The Dock & Harbour Authority

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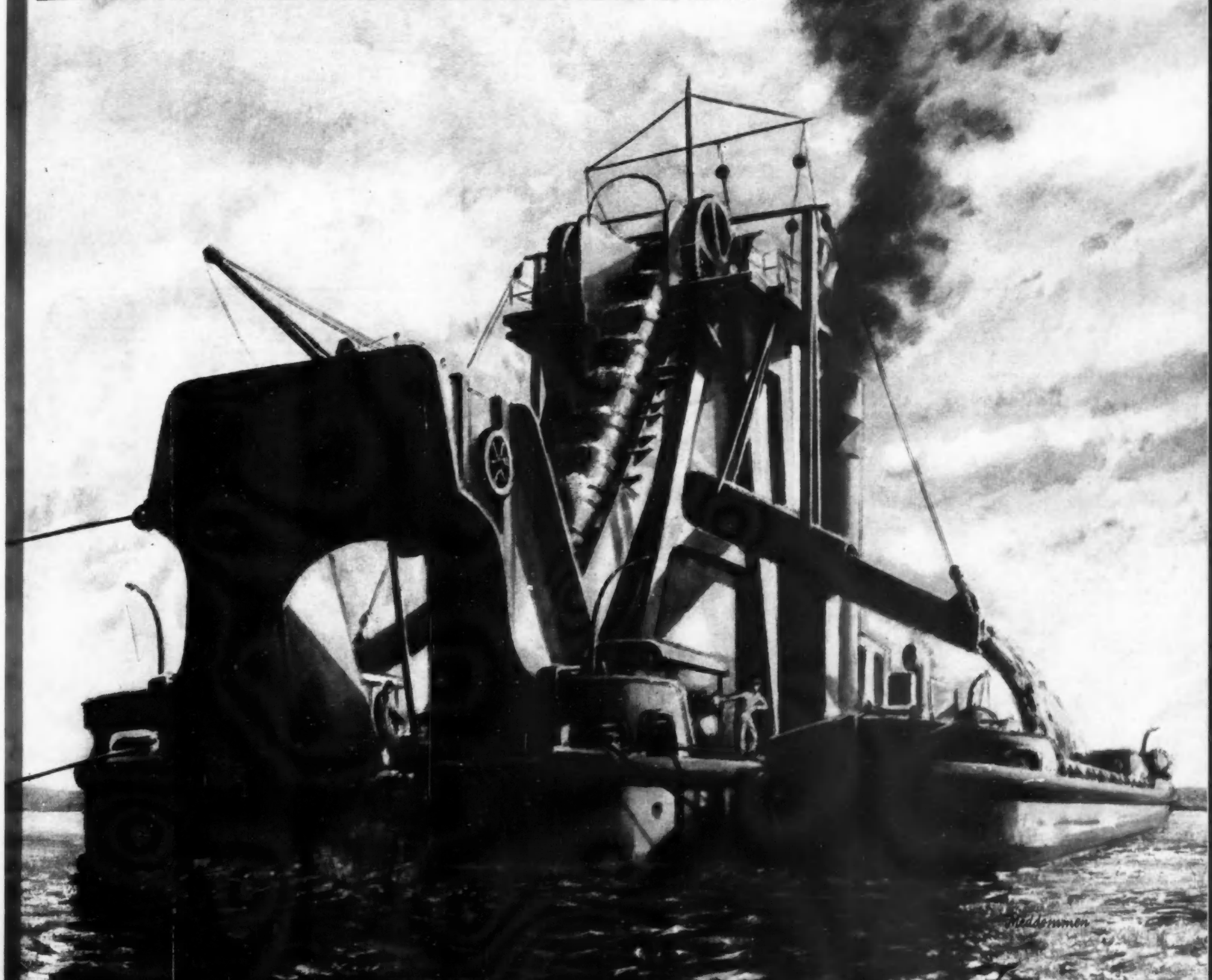

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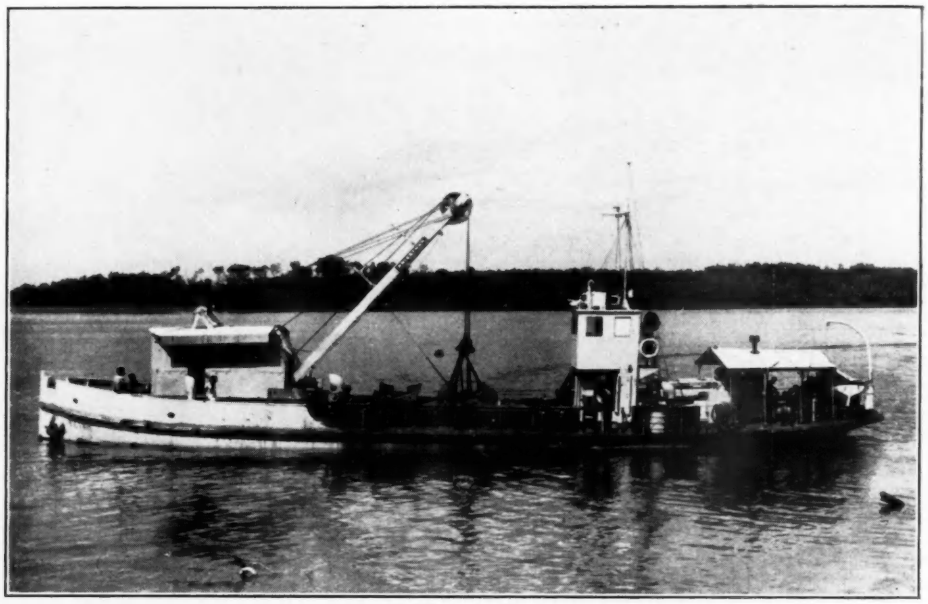

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The Dock & Harbour Authority

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No. 392

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Editorial Comments

The Dover Car Ferry Terminal.

The gradual development of the Port of Dover throughout the centuries, owing to its advantageous geographical proximity to the Continent of Europe, is perhaps a logical sequence of events, and has been dealt with in this Journal on a previous occasion (see the March, 1951, issue).

From an engineering point of view, the works constructed during the last 100 years are of considerable interest. The building of the original Admiralty Pier in 1847 and that of the subsequent Admiralty Harbour, completed in 1909, are generally acknowledged as great feats of marine constructional engineering. For several years thereafter the Port of Dover operated as two distinct undertakings, Naval and Commercial, until, in 1929, the Dover Harbour Board was given control of the whole of the installations.

Dover being the nearest British harbour to the Continental ports of Calais, Boulogne, Ostend and Dunkirk, the principal trade is naturally cross-channel traffic, including passengers, accompanied cars and cargo of various kinds, which totals about 600,000 tons per annum, inwards and outwards.

The Train Ferry operating from an enclosed dock was an innovation of considerable importance built during the years 1933-1936, the specially constructed Train Ferry vessels being capable of carrying 12 sleeping coaches and 30 motor cars. Owing to the growth of the accompanied car traffic, however, these facilities became inadequate, and the Car Ferry Terminal, which is the subject of our leading article this month, was planned and put into execution as soon as post-war conditions permitted. It will come into full operation next month.

Readers will observe with interest the general layout and planning of the facilities which, besides passengers, are designed to deal with 240 cars per hour. The unique system of fendering of the jetties, which are liable to heavy wear and tear during berthing operations, is also worthy of note.

The transhipment of accompanied cars is regarded by the authorities as one of the most important factors in the future of the Port of Dover. Ever mindful, however, of the port's position as the "Gateway to England" the development of other potentialities are being considered, and we hope to be able to publish details of these further improvements at a later date.

Prevention of Corrosion of Marine Structures.

This issue contains (page 47) the first instalment of an article on "The Corrosion of Iron and Steel and Its Prevention with Special Reference to Harbour and Dock Installations" by Dr. J. C. Hudson, Head of the Corrosion Laboratory of the British Iron and Steel Research Association.

The importance of corrosion and conservation and preservation of metals, and the growing economic implications of the matter, was stressed in our January issue, when a general survey of recent research work and the nature of corrosive action was published. Its prominence as a factor in the maintenance of maritime plant and structures was commented upon in our May number, when practical problems that arise were discussed in an introductory article to the forthcoming series referred to above.

The development of corrosion research and paint technology has taken great strides during the past three decades, and the non-specialist cannot but find great difficulty in keeping pace. The article by our contributor, an acknowledged world authority on the subject, should therefore prove of great value to those engaged in dock and ship maintenance.

The first essential is an understanding of the principles governing corrosion and these are reviewed in the first instalment. Consideration is then given to corrosion of iron and steel under three headings, viz., "Atmospheric," "Marine," and "Soil," reference being made to experiments and findings in many parts of the world, together with the behaviour of low-alloy and rust-resisting steels. There follows a comprehensive survey of rust prevention measures, which covers, *inter alia*, surface preparation, protective coatings and cathodic protection. Finally, details are given of a number of diverse corrosion problems covering a wide field, concluding with practical recommendations for sound anti-corrosion measures. A short selected bibliography of major publications covering the most important aspects of the subject is appended for ready reference.

Corrosion is a powerful enemy of efficiency, and the cause of considerable unproductive expenditure, and to combat it much skill and effort is being exerted in continuous research, by private organisations and institutions having a semi-offical or official character. It is vital that the research findings and the means of their practical application be made widely known, and it is hoped that the publication of this comprehensive article will go some way towards that end.

Tonnage Measurement of Ships.

Discussions on tonnage measurement have taken place from time to time since Matthew Baker devised the first rule for computing ship tonnage in 1582. This method consisted of multiplying the length by the breadth by the depth of the ship, and then dividing the result by the sum of the factors. The resulting tonnage was known as the "burden" to which was added one-third of the "burden" to obtain the deadweight tonnage. The present method of computing tonnage, the "Moorsom" system, was invented in 1852.

It was in the 1920's that Dr. Bruhn, an eminent Naval Architect, stated that "due to the continuous scientific instruments to the original system introduced by Mr. Moorsom a complete Chinese puzzle has been created. At some time a change will, however, have to be made, whereby tonnage regulations must be brought into line with modern practical requirements."

Moorsom's Tonnage Rules, explained elsewhere in this issue, have been adopted by all maritime nations although certain countries have varied their application. It was in consequence of this variation that the League of Nations set up a technical committee on maritime tonnage measurement, and in 1928 they issued a report dealing with the differences in the existing rules and in their application, and submitted the establishment of a uniform method of tonnage measurement based on the British method. The outcome of the committee's work was the "Draft Regulations for the Tonnage Measurement of Ships, 1931," which was distributed to all maritime nations but was received with apathy. More success, however, was achieved at an international conference, held in Oslo in June, 1947, where Great Britain and the United States were represented as observers. Here the wording of a new inter-

Editorial Comments—continued

national convention of uniform tonnage measurement was agreed, and signed, by seven European countries and Iceland.

Tonnage measurement experts from Denmark, Finland, France, Holland, Norway and Sweden met at Gothenburg early this year to discuss a British proposal for the modification of the existing rules governing the amount of propelling power space to be deducted from the gross tonnage to obtain the net register tonnage. The proposal has now been put to all countries having reciprocal agreements with the United Kingdom for the mutual acceptance of tonnage certificates, as well as the signatories to the Oslo Convention. It concerns vessels with engine rooms of 13 per cent., or less, of their gross tonnage; and provides that the existing allowance of 1.75 times the actual engine room space, should be replaced by a graduated scale to fall into line with the liberal deduction of 32 per cent. of the gross tonnage which is allowed to ships with engine rooms of over 13 per cent. and under 20 per cent. of the gross tonnage.

The proposals are that a vessel with an engine room of 13 per cent. of the gross tonnage would be allowed a deduction of 32 per cent. of the gross tonnage; a vessel with an engine room of 12 per cent. of the gross tonnage would be allowed a deduction of 12/13ths of 32 per cent., and so on.

To get the maximum tonnage reduction in the existing tonnage rules a shipowner needs to have an engine room of at least 13 per cent. of the gross tonnage. This may be larger than necessary resulting in an uneconomic ship. The proposal encourages efficiency in shipbuilding by the provision of smaller engine rooms without the consequent big increases in net register tonnage.

This proposed modification of propelling power allowance is an interim measure, taken during the interval elapsing while the Inter-Governmental Maritime Consultative Organisation starts to function, for it has been agreed that one of the first problems that the Organisation will consider is the unification of maritime tonnage measurement.

Authoritative Views on Britain's Inland Waterways.

On a following page will be found a short article by Sir Reginald Hill, Chairman of the Docks and Inland Waterways Executive, in which he reviews the present state and recent achievements of the British Inland Waterways Industry, and also gives some indication of future intentions. The clear statement that, freed from the responsibility for canals which have little traffic potential, the commercially active waterways could more than cover the costs of maintenance and operation is very welcome, particularly since it is clearly authoritative. We have frequently referred to the urgent need for a decision upon a future policy for British waterways, and upon the disposal of those of little commercial utility. This is also a problem to be faced in other countries, and the effect of decisions in Great Britain will be followed with interest in all parts of the world.

If the active canals only are to remain under the Transport Commission, the apparently obvious solution to the problem of the 800 miles of little-used canals lies in their transfer to other authorities better suited to exploit their potentialities, other than commercial transport, or to keep them in existence for their amenity value or as drainage or water-supply channels. The difficulties to be faced in disposing of these redundant stretches of waterway are enormous, but some practical steps must be taken very soon. Furthermore, abandonment of navigation, whilst the responsibility of ownership remains, would not provide much relief, nor would it be easy in the face of the public outcry, which would probably follow its announcement.

Nevertheless, if the Docks and Inland Waterways Executive were responsible only for the canals capable of commercial exploitation, it would be possible to prove that these were being managed efficiently and that modern operation methods were being adopted. Attention could also be directed to preparing and publishing a plan for large scale enlargement of selected canals, to be undertaken when economic conditions permit. What is important is that the authority responsible for the commercially active canals should no longer be encumbered by "dead wood," as Sir Reginald Hill calls it. Whether this authority need also be associated with port operation and ownership is another matter. Indeed, the separation of the two activities and the establishment of a distinct authority to concentrate upon the commercially active waterways, has already been advocated in some quarters.

Canals with Little Traffic Potential.

Arising from the foregoing is the question of the future of those canals which the Docks and Inland Waterways Executive does not want, but which must remain in existence, so that they may serve other functions, such as drainage, water supply, pleasure and amenity. The difficulty simply lies in their disposal, since they are precisely those which will not earn sufficient revenue to meet expenses, and other authorities will therefore hesitate to accept them on any terms.

There appear to be two solutions; either by governmental intervention, these 800 miles should be transferred to River Boards, County Councils, or even voluntary bodies; or alternatively, the Executive, or some authority replacing it, should receive financial assistance to meet the costs arising from the maintenance of canals for purposes other than commercial navigation. If it were a new Board which took over both the profitable and unprofitable canals, its activities should logically be integrated with those of existing River Boards and Water Undertakings. This step, however, would mean considerable re-organisation and upheaval in more fields than that of canal transport. There are other objections too, the chief being that an important branch of nationalised transport would no longer be controlled by the Transport Commission. Furthermore, the accounts for commercial transport would then become confused with the costs of maintaining waterways for other purposes. This obscurity, and the consequent difficulty in critically assessing the operational efficiency of the transport undertaking, would not be in the public interest It is hard enough already to ensure that nationalised undertakings are run efficiently, and in an enterprising way, without creating further difficulties.

Increased Trade at U.K. Ports.

Encouraging figures showing an overall increase in activity in the maritime trade of the United Kingdom are given in the "Board of Trade Journal" for the first quarter of 1953. The total net tonnage of vessels in the foreign trade entering with cargo at United Kingdom ports was 15,400,000 tons. The daily average was 2 per cent. higher than in the fourth quarter of 1952 and 5 per cent. higher than in the first quarter of that year. Clearances with cargo were 11,500,000 tons net, the daily average showing an increase of 1 per cent. over the previous quarter and 10 per cent. compared with a year ago. The figures of both entrances and clearances were the highest recorded for a first quarter since 1939.

Foreign tonnage accounted for 44 per cent. of the total entrances with cargo, the proportion for the first and fourth quarters of 1952 being 44 and 41 per cent. respectively. For clearances with cargo the proportion was 37 per cent. compared with 34 per cent. in the last quarter of 1952 and 33 per cent. for the corresponding period last year.

Arrivals with cargo in the foreign trade at the majority of ports in the United Kingdom were higher than in the corresponding period of 1952. At London there was an increase of 271,000 tons net (7 per cent.), while Liverpool and Southampton showed increases of 312,000 (14 per cent.), and 343,000 (18 per cent.) tons net, respectively. Arrivals at Hull were the highest for any quarter for over three years, and at Bristol the highest for any quarter since the war. Glasgow, Belfast and Swansea also recorded higher figures than in the first quarter of last year.

Total departures with cargo in the foreign trade were slightly lower than the last quarter of 1952. Compared with the corresponding period of 1952, however, they were about 10 per cent. higher. London, with an increase of 235,000 tons net, recorded the highest figure of departures for any quarter since the war, as also did Lancaster, Manchester and Middlesbrough. The Grimsby figure rose by 128,000 tons, and was the highest for any quarter for over three years, while departures from Southampton, Glasgow and Hull were higher than in the first quarter of 1952.

Among the ports which showed decreases in departures compared with the first quarter of 1952 were Liverpool with 40,000 tons less, the lowest figure since the second quarter of 1949; Greenock with 28,000 tons less, the lowest figure since the fourth quarter of 1946, and Dover, Folkestone and Harwich with decreases of 6,000, 40,000 and 67,000 tons net, respectively.

Dover Car Ferry Terminal

Modern Facilities for Developing Continental Traffic

THE Car Ferry Terminal at the Eastern Docks, Dover, was planned, is being constructed, and will be operated by the Dover Harbour Board. It will be the first installation of its kind in the United Kingdom and involves an expenditure of about three-quarters of a million pounds.

The Terminal was planned immediately after the second World War to provide the essential facilities required to accommodate the rapidly developing traffic of accompanied cars and coaches to and from the Continental Ports served by Dover. This traffic may be said to have grown into definite trade in 1928; prior to that year it had been of only minor importance. Only occasional cars to and from the Continent were carried on the passenger steamers plying to Calais, Boulogne and Ostend, and there was no necessity for any special organisation at the Channel Ports on this account. In 1928, however, Captain S. M. Townsend, of the firm of Townsend Bros. Ferries Ltd., chartered vessels for the express purpose of conveying motor vehicles between Dover and Calais, and other shipping operators followed the same course a year later. At this period the number of cars handled annually was about 6,000. Subsequently, the services were operated by ships specially designed for the conveyance of motor vehicles and affording passenger accommodation for the convenience of motorists travelling with their cars. To-day the channel crossings are served by modern, fast and well-appointed car-carrying vessels including the *Lord Warden*, the *Dinard*, the *Halladale*, and the *Prinses Josephine Charlotte*, all with stern loading facilities to permit direct drive on and off the vessels on either side of the Channel.

The rapid growth of accompanied car traffic since the war (quite apart from the export of new cars) is revealed by the following statistics to the 31st March for each of the following years:

Year	Vehicles	Year	Vehicles
1939	31,336	1950	70,450
1947	7,593	1951	94,635
1948	32,388	1952	107,020
1949	42,301	1953	100,993

The growth of the traffic had, however, outpaced the development of the port facilities. Cars were handled by cranes, except at the Train Ferry Dock, which came into operation in 1936, where the direct loading facilities provided for the train ferries were used by a considerable number of cars proceeding to Dunkirk. Shore facilities generally were totally inadequate, more particularly at the Western Docks, and cars were subject to long delays before shipment or after discharge from the carrying vessel. This position was unavoidable, in that the dockside accommodation in use was not laid out to deal with this particular type of traffic, but rather for passenger traffic which in itself calls for special port facilities unsuitable for handling accompanied cars requiring ample manœuvring space.

It was to remedy this state of affairs that the designing of a new car ferry terminal was decided upon. As soon as post-war conditions permitted, the Harbour Board's engineers completed their plans and the works were actually commenced in October 1951 and will be substantially completed by October next, although the terminal will be in full operational use during the summer of this year. With the inauguration of the new shore facilities all the car ferry vessels will operate from the Eastern Docks, where the greater proportion of the traffic will be dealt with whilst at the Western Docks, apart from the train ferries, there will be only a small number of cars handled by the Calais or Ostend mail or passenger steamers.

Partial (one-bridge) loading commenced operation in April, for use by Messrs. Townsend Bros. Ferries' vessel *Halladale*, which normally operates from the Eastern Docks. The terminal will be brought into full operation on the 4th July, when it will accommodate the following vessels:

The British Railway Executive's *Lord Warden* (capacity 130 cars) and *Dinard* (capacity 80 cars) for services to and from Boulogne.

Messrs. Townsend Bros. Ferries' *Halladale* (capacity 55 cars) for services to and from Calais.

The Belgian Marine Administration's *Prinses Josephine Charlotte* (capacity 120 cars) for services to and from Ostend.

During the summer there will be up to seven arrivals and seven departures at and from the terminal daily.

The car ferry terminal is capable of handling all the traffic envisaged for several years. Accommodation is provided for two vessels to load or discharge simultaneously. A similar number of vessels can be accommodated on the other side of the Channel, and allowance must also be made for vessels on passage whereby the provision at Dover will be adequate for many years to come.

Portal Towers under construction showing loading bridges and s.s. *Halladale* discharging at Eastern berth. Entrance to Camber from Outer Harbour in distance.

The main objectives of the terminal are speed, comfort and simplicity, and its chief features are:

(1) Loading Berths:

Two entirely new loading berths are provided with depth of water of 21-ft. at L.W.O.S.T. Each berth is served by loading bridges to enable cars and coaches to drive directly on board, thus making it unnecessary to load vehicles by crane. The berths are each 400-ft. long and 72-ft. in width, and are designed to handle vessels of between 300-ft. and 400-ft. in length and between 35-ft. and 55-ft. beam.

The berths have been constructed in the Camber at the Eastern Docks by widening the existing West Jetty by 10-ft. and constructing two additional jetties parallel with the West Jetty enclosing the two berths. The new jetties consist of a series of concrete dolphins formed of Appleby-Frodingham No. 2 section steel sheet piling; driven in the form of cofferdams approximately 30-ft. square. The piling is driven approximately 5-ft. into the chalk and is cut off at 2-ft. 6-in. above L.W.O.S.T. After cleaning out the mud and soft chalk from the inside of the cofferdams they were filled with mass concrete placed under water by tremie. Above the piling level the dolphins are constructed in mass concrete cast inside timber shutters. The central jetty is composed of two isolated dolphins, whereas the eastern jetty is formed by three dolphins linked together by steel footbridges. The head dolphins to each jetty are approximately twice the size of the normal fender system to pre-

Dover Car Ferry Terminal—continued

General layout showing Petrol Station and Car Park in foreground, Reception Building (two-storied) and Customs Examination Hall beyond, and loading berths in background.

vent damage to shipping and dolphins during berthing operations. At the shore end of the berths five dolphins are constructed in a similar manner to the berthing dolphins and upon these the ferro-concrete portals have been constructed.

The vessels operating in these berths are specially built for stern loading, and are of a twin-screw type and fitted with bow rudders to enable speedy manœuvring into the berth stern first. Two berths are also available for ships to lay-by. The loading berth adjacent to the West Jetty is served by a 4-ton electric crane for loading or discharging ships' stores, etc. Other necessary services provided at all berths are water, fuel oil and electricity supplies (both direct and alternating current).

A total of 33,000 tons of concrete was used in the marine works, together with 1,600 tons of steel in the whole terminal.

(2) **Access or Loading Bridges, Ramps, etc.:**

Access from the shore to each loading berth is by means of a short ramp leading from the car park to the loading bridge, and from the seaward end of the bridge to the ship's deck over a short link span. The bridges, which are 140-ft. long, and weigh 230 tons, are hinged at the land end and are raised or lowered at the seaward end by means of hoisting machinery situated in the reinforced concrete portals. The movement of each bridge is arranged so that it automatically follows the level of the deck of the ship as it varies with the tide or loading. Vessels can be loaded at all states of the tide, and even in extreme tides loading can proceed provided the deck is between 6-ft. and 18-ft. 6-in. above water level.

The range of ordinary spring tides is 18-ft. 9-in., but for the purpose of the design the overall range has been taken as being 22-ft. This means that the vertical movement of the bridges at seaward end is 34-ft. 6-in. (i.e. cars can be loaded on to the lowest deck of the vessel at the lowest low water and on to the highest deck at the highest high water). The bridges and accessory gear are suspended inside the portals and the dead loads are balanced by two counterweights in the wings of each portal. The live load is carried by the main hoisting winch, which is situated in the machine room immediately over either bridge. The main control of each set of machinery is from the control desk inside the control building between the two portals. Hoisting and lowering can be carried out under manual control from this control room and after the link span has been lowered on to the deck of the ship the automatic control gear can be brought into operation. The automatic limit switches are situated underneath the link span and are operated by the variations in angle of the span itself, and control is therefore regulated directly by the level of the ship's deck. The portal towers rise 87-ft. above low water level and are 108-ft. above the chalk foundation.

(3) **Customs Examination Hall:**

This spacious building, giving 42,000 square feet of covered accommodation, has been planned to handle 240 cars per hour. Car and baggage examination islands laid out in herring-bone fashion are provided to permit of a constant flow of traffic without interruption.

The building is constructed in two bays with galvanised steel roof trusses of 95-ft. span. The roof is sheeted with corrugated asbestos and is lined with Tentest boarding. Offices have been constructed inside the building for use of H.M. Customs, Immigration, Health Authorities and the Touring Clubs. The whole building is provided with ample roof glazing and is lighted at night with fluorescent lighting.

Sited in a central position overlooking the whole hall is a control room which contains public address equipment and automatic telephones communicating with all offices, car parks, berths and the reception building. This means of control will facilitate the continuous flow of traffic.

(4) **Reception Building:**

The reception building affords facilities in the main hall for banking, post office, buffet, shop, telephones, waiting and cloakrooms for passengers, and offices for the shipping operators and the A.A. and R.A.C.; also, on the upper floors, office accommodation for Government Departments and others concerned.

The building is a steel framed structure clad in brick and concrete, with large windows in the modern style, which from the main reception hall and buffet afford clear views over the harbour.

(5) **Reception and Marshalling Car Parks and Roads:**

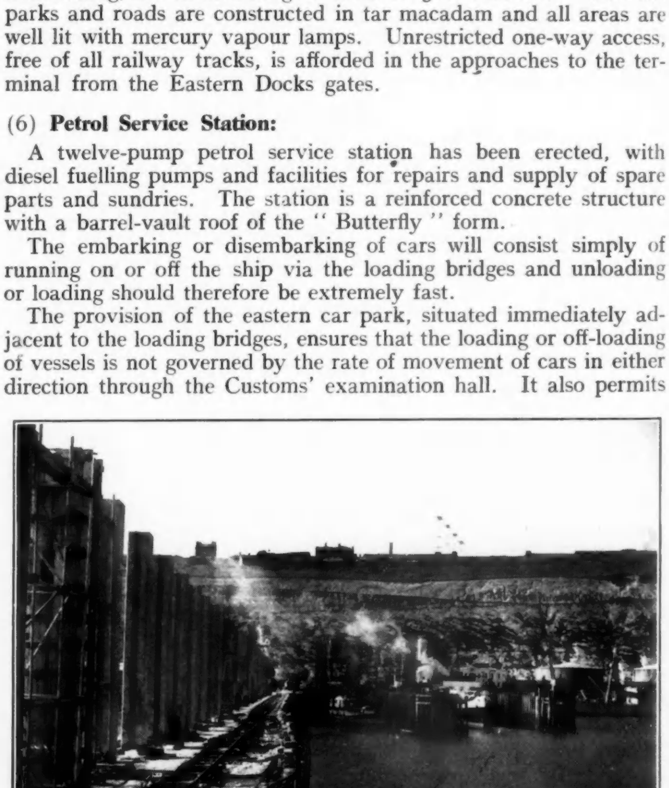
Two extensive car parks have been provided for reception and marshalling, accommodating a total of 500 vehicles. The car parks and roads are constructed in tar macadam and all areas are well lit with mercury vapour lamps. Unrestricted one-way access, free of all railway tracks, is afforded in the approaches to the terminal from the Eastern Docks gates.

(6) **Petrol Service Station:**

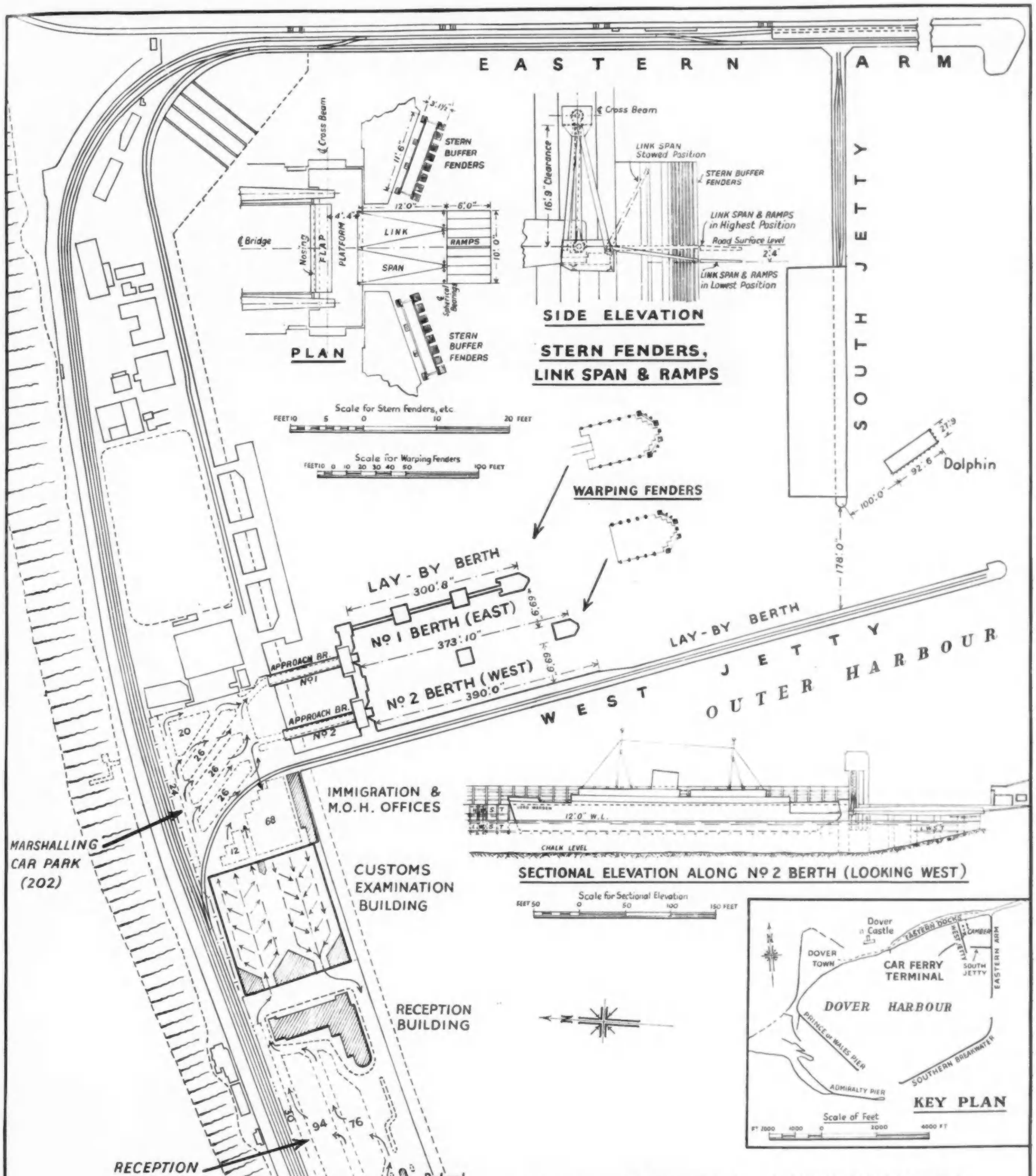
A twelve-pump petrol service station has been erected, with diesel fuelling pumps and facilities for repairs and supply of spare parts and sundries. The station is a reinforced concrete structure with a barrel-vault roof of the " Butterfly " form.

The embarking or disembarking of cars will consist simply of running on or off the ship via the loading bridges and unloading or loading should therefore be extremely fast.

The provision of the eastern car park, situated immediately adjacent to the loading bridges, ensures that the loading or off-loading of vessels is not governed by the rate of movement of cars in either direction through the Customs' examination hall. It also permits



Car Ferry berths showing wind protection wall on West Jetty, The Camber, under construction.



EASTERN ARM
SOUTH JETTY
PLAN
SIDE ELEVATION
STERN FENDERS, LINK SPAN & RAMPS
STERN BUFFER FENDERS
LINK
SPAN
RAMPS
FLAP
PLATFORM
Nosing
Bridge
Cross Beam
LINK SPAN Stowed Position
LINK SPAN & RAMPS in Highest Position
Road Surface Level
LINK SPAN & RAMPS in Lowest Position
16'9" Clearance
Scale for Stern Fenders, etc.
Scale for Warping Fenders
WARPING FENDERS
Dolphin
LAY-BY BERTH
300'8"
Nº 1 BERTH (EAST)
373'10"
Nº 2 BERTH (WEST)
390'0"
APPROACH BR. Nº1
APPROACH BR. Nº2
LAY-BY BERTH
WEST JETTY
OUTER HARBOUR
178'0"
100'0"
92'6"
IMMIGRATION & M.O.H. OFFICES
MARSHALLING CAR PARK (202)
CUSTOMS EXAMINATION BUILDING
RECEPTION BUILDING
RECEPTION CAR PARK (200)
Petrol Station
RESERVE CAR PARK (100)
SECTIONAL ELEVATION ALONG Nº 2 BERTH (LOOKING WEST)
12'0" W.L.
CHALK LEVEL
Scale for Sectional Elevation
KEY PLAN
Dover Castle
DOVER TOWN
CAR FERRY TERMINAL
DOVER HARBOUR
EASTERN DOCKS
SOUTH JETTY
EASTERN ARM
PRINCE OF WALES PIER
ADMIRALTY PIER
SOUTHERN BREAKWATER
Scale of Feet
CAR FERRY TERMINAL
— DOVER —
Scale of Feet
FEET 100 50 0 100 200 300 400 500 600 FEET

Dover Car Ferry Terminal—*continued*

Portion of North wing of Customs Examination Hall.

of inward or outward traffic passing simultaneously through this hall.

The general design for the whole lay-out provides for the largest road vehicle being handled, with ample margin for development. Progress through the terminal is an extremely simple matter. In the case of outward bound traffic, cars proceed from the Eastern Docks entrance to the west (or reception) car park, some 500 yards distant, by a wide straight road. Cars are marshalled therein on arrival in traffic lanes for the particular port of destination, i.e. Boulogne, Calais or Ostend. The various shipping operators' offices, touring associations, retiring rooms, buffet, shop, etc., are immediately available in the adjacent reception building. The driver having arrived with time in hand will be advised by notice board, or public address system, of the scheduled time of movement from his traffic lane for examination and loading into vessel. At this stated time, cars, complete with all passengers, will then pass from the reception car park to the main Customs hall a short distance away. Immigration and Customs formalities will be completed in this hall, whereafter cars pass straight on board ship by the loading bridges.

Inward bound traffic proceeds direct off the ship through the east car park to the Customs examination hall, and the reverse procedure follows as to examination etc. Once the motorist has passed out of the Customs hall all formalities will have been completed, and he is free to park in the reception area, take refreshment in the buffet or refuel his car before proceeding on his journey.

An important point of the whole scheme is that it is a highly flexible one, capable of adaptation to suit varying circumstances.

The Fender System.

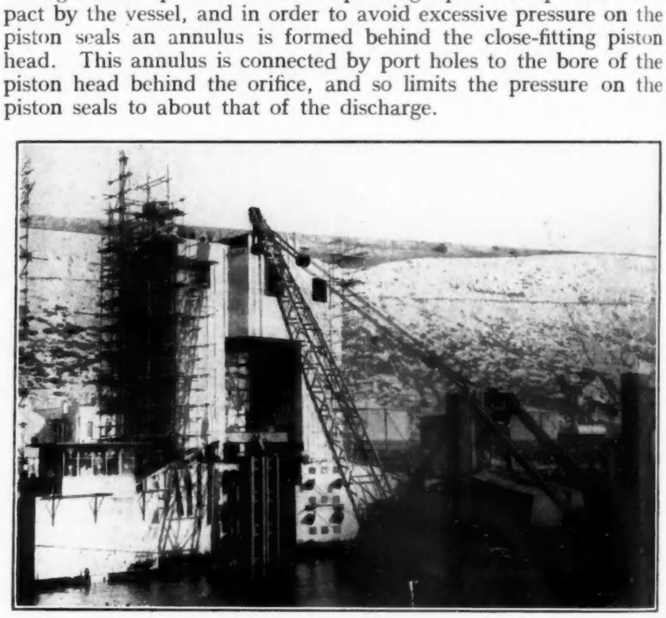
The Fender system to absorb the kinetic energy of vessels when berthing stern-on is unique and is the first of its type in public service. Each berth is provided with two fenders suspended by chains from steel work anchorages built into the concrete berth walls, and the fenders are of heavy steel work mattress construction incorporating high capacity hydraulic buffers. The outer faces of the fenders are provided with 12-in. square vertical fender timbers and the buffers are mounted in the mattress frames in such manner that the buffer plungers impact on wearing plates inset in the concrete walling.

In order to cushion the impacting force of vessels up to 3,000 tons dead weight berthing at relatively high speed, allowance has been made for 2-ft. per second, and to absorb energy of the order of 2,220 inch/tons 15 hydraulic buffers per fender are employed. Each buffer having 5-in. working stroke with an energy absorption capacity of 370 inch/tons at an impact velocity of 2-ft. per second.

In designing the fender it was assumed that a minimum of 6 buffers would come into action at any one time. A notable feature in this application of buffers is that they are not self-contained as is the case when fitted on railway rolling stock or other moving vehicles, but the buffers on each fender are coupled in vertical legs of five to a manifold pipe which connects to a pressure control vessel mounted in the fender mattress near to the top. This arrangement permits the hydraulic oil displaced during the buffing or compression stroke to discharge into the control vessels against the initial air pressure. The control vessels are in effect hydraulic accumulators receiving oil under pressure from the buffers and returning it to them when the load is removed.

The buffer units employed comprise a case, a plunger and a piston all made from steel forgings, and in regard to the plunger this is of high tensile steel to withstand the high pressures generated. The case is a guide in which the plunger telescopes, and is provided with a flanged base for connecting to the fender frames. The plunger is also a hydraulic cylinder and telescopes over the piston as well as in the case. The piston is bored hollow to admit a fluted throttle stem which is secured to the inside of the head of the plunger. When the buffer is compressed the area for flow through the throttle flutes diminishes, thus causing the buffer to exert a substantially constant force throughout the whole of the stroke. The pressure drop across the orifice is proportional to the square of the speed at any instant so the stroke is substantially constant for all speeds of impact and the energy of the vessel berthing is also proportional to the square of the speed.

Extremely high pressures may be generated in the cylinder during the compression stroke depending upon the speed of impact by the vessel, and in order to avoid excessive pressure on the piston seals an annulus is formed behind the close-fitting piston head. This annulus is connected by port holes to the bore of the piston head behind the orifice, and so limits the pressure on the piston seals to about that of the discharge.



One of the fenders being lifted into position by floating crane.

According to the state of the tides most of the buffers operate under water, therefore, efficient gland type seals with high pressure lubrication are provided to prevent the ingress of water into the buffers and in addition to the hydraulic manifold, each buffer is connected to one central lubrication point on the top fender frame. Thus all servicing and pressure checking is readily performed at deck level.

Undoubtedly these are the largest and highest capacity buffered fenders in service in the world and the reason for their magnitude can be appreciated when the range of 18-ft. 9-in. between H.W.O.S.T. and L.W.O.S.T. is taken into consideration together with the variation in the beltings of the several ships employed in the service.

The steelwork for the fenders and fender supports are to the design of the Dover Harbour Board, and George Turton Platts and Co. Ltd. are responsible for the construction, also for the design of the buffers and the hydraulic and lubrication systems.

Cargo Handling Problems of the Shipowner

Need for Efficient and Modern Methods*

By ARTHUR H. GURR.
(Outward Freight Manager, Clan Line Steamers Ltd.)

IF you ever have an opportunity of seeing the final stowage plan of a ship which has loaded, say, 12,000 freight tons of general cargo from three or four loading ports, to five or six ports of discharge you would see it is almost a work of art. Think of the planning and forethought which go into laying out the holds and decks before any cargo is loaded, bearing in mind the ultimate stability of the ship and her trim. To ensure progressive loading there must be co-operation by those involved, particularly in regard to delivery arrangements from works to docks. Suppliers should take care to comply with the forwarding requirements of the Loading Agents, whose aim is to see that the arrivals of cargo marry up with the stowage.

At many ports as well as those of South Wales, general cargo berths are served by rail direct from the main lines and it is practicable to load direct to ship from rail wagons, if the loads are complete parcels, and are in separate wagons for individual destinations. It is important to give timely advice to Loading Agents of the truck numbers and details of their contents, as well as ensuring that the trucks are fully labelled and consigned to the appropriate dock and loading berth. All this is elementary but sometimes is overlooked. To avoid incurring wagon demurrage, delivery should not be made earlier than the requested date. Where small consignments or mixed destinations are concerned, it is unlikely that direct shipment can be arranged, but normally such wagons are discharged to transit sheds for sorting (for which appropriate charges are levied by the dock authorities).

With regard to road traffic there should be no undue difficulty in handling promptly ex lorries provided senders give sufficient notice of intended arrivals to the dock authorities to enable sufficient strength of labour to be made available. Senders can help considerably by giving warning of road movements. In most cases it is necessary to discharge lorries into transit sheds, although occasionally direct shipment can be arranged when stowage permits.

Congestion of vehicles can be avoided altogether if you give prior advice of expected time of their arrival so that the planning of vehicle reception can be organised. It is naturally to the advantage of shipowners to know that manufacturers can rely on the prompt release of their vehicles, as this will encourage their increased use.

The sellers' market is over, and manufacturers are being priced out of some markets; therefore any saving in costs should help in these days of growing competition. The more you route your cargo through your nearest port, which in the case of this meeting would be a South Wales port, the greater the chance of the various conference cargo liner companies giving regular service.

Quite a number of ships are advertised to load at Swansea or Newport "subject to inducement." Some Lines in their anxiety to give you a regular service send in their vesesls virtually "on trust." We do rely on manufacturers doing all possible to justify their insistence on this regular service. Sometimes due to insufficient inducement it becomes necessary for cargo booked to be coasted to the vessel's next loading port, provided shippers are agreeable to this procedure, and the cargo is of the type and packed in such a manner as to stand up to the extra handlings involved in transhipment. For example, cargo in paper bags is not considered suitable. Where transhipment takes place it is normally at the expense of the shipowner but at the risk of the shippers.

Sometimes manufacturers appear to incur extra expenses quite needlessly. We have loaded at Birkenhead cargo which has been sent up from South Wales and which was despatched whilst the ship in question was already loading at Newport or Swansea. Perhaps I should explain that I have not mentioned Cardiff as that is not a berth port in the trades served by my company. As regards manufacturers in North Wales, they will naturally route their cargo via Birkenhead or Liverpool.

It must be admitted that generally the duration of voyage from South Wales to destination is longer, because of the need for most vessels to complete loading at Liverpool, where top stowage cargo is available. But when cargo is plentiful, shippers at last port of loading run the risk of having their consignments shut out, whereas that rarely (if ever) happens at Newport or Swansea. Occasionally the Bristol Channel area serves as last port of loading but in the main the type of cargo available there is bottom stowage. Now and again there is a large quantity of suitable light cargo for first discharge port which enables a South Wales port to become last loading port, but this is the exception.

To build up a cargo to fill a vessel is a fascinating, worrying and sometimes a frustrating occupation, but always most interesting with some new lesson to learn. Now and again we achieve what is known as a shipowner's dream, that is, a ship which is not only down to her marks, but is also full. With a miscellaneous general cargo that is very difficult to achieve and requires careful selection of cargo, some skill and much luck! One of our problems is to secure the right combination of cargo and we need to know the measurement per ton weight of every type of cargo. For example, tinplates measures 8-ft. per 20 cwts., cement in bags 32-ft., steel sleepers, nested, 22-ft., rails 12-ft., cork slabs 250-ft., unpacked motor cars about 400-ft. These factors are borne in mind when arranging stowage and occasionally it is possible to secure the right assortment of cargo to give the perfect stow, say, to floor over the lower holds with steel rails, place stillages of tinplates in the 'tween decks on top of which can be stowed, say, cases of washing machines and similar light measurement cargo. The selection of the goods necessary to build up a balanced cargo was much more simple for the first few years after the war when registration systems were in general operation in most trades, whereas now it has in the main reverted to the pre-war practice of "catch as catch can," within conference framework.

Heavy Lift Problems

With regard to ships with heavy derricks and the type of cargo with which they deal, those engaged in securing cargo must have a full knowledge of the capacity of each ship, and the size of her hatches. Every heavy lift brings its own problem of stowage. and technical advice is needed on the subject of stresses, strains, outreach and the like.

Last December our "Clan Cumming" discharged at Capetown a stator weighing 94 tons. This had to go by a ship with the necessary gear (she has a derrick of 105 tons) because the heaviest lift which can be tackled by harbour crane at Capetown is 60 tons. Furthermore, we had to deliver the stator 14-ft. 6-in. from the ship's side in order that it could be placed direct on to a railway truck, which took it to its final destination. The ship's derrick therefore had to have the necessary outreach.

During March our "Clan Chattan" loaded at Glasgow six locomotives for Mombasa weighing about 62 tons each, and these could only be taken by a vessel capable of lifting 80 tons, bearing in mind that a special locomotive lifting beam may weigh anything up to say 12 tons. The heaviest crane amongst harbour facilities at Mombasa is 10 tons. Clearly, ship and port facilities must always be kept in mind when accepting lifts; are the lifts within the capacity of the derrick at the hatch in which they are to be stowed; or alternatively can the harbour appliances at both ends deal with them?

Occasionally something goes wrong and this entails a great deal of staff work to rectify, as the two following examples will show.

*Extracts from a Paper read at the Convention of the Industrial Association of Wales and Monmouthshire, May, 1953.

Cargo Handling Problems of the Shipowner—continued

A few years ago, a piece of machinery weighing 14½ tons was accepted for Mauritius, the booking clerk having checked from the office records that there was on the quay at Mauritius a 15-ton crane. Unfortunately however, that crane is only capable of lifting cargo from a lighter to the quay, and cannot plumb the holds or deck of an ocean steamer, which meant that the ship herself needed to discharge the package into a lighter at the anchorage, but as she had only a 10-ton derrick, she had to return to Durban where the package was taken out by floating crane and transferred to the next vessel going to Mauritius which could tackle the package with her own gear. Quite a costly business.

Recently a heavy-lift ship arrived at Beira carrying two locomotives each weighing 64 tons, stowed in No. 2 lower hold. Whilst the first locomotive was being lifted, something came adrift in the 80-ton derrick. A very tense few minutes followed, but by clever manipulation the locomotive was landed on deck of the steamer. Of course, it could have been most serious; it could have dropped right through the bottom of the ship; luckily this did not happen, but the owners were faced with the problem of a ship at Beira, having discharged her general cargo, but with two locomotives which could not be taken off. Therefore, this ship had to return to Durban, where the shore crane of 80 tons put the locomotives on the quay for transfer to the next Clan vessel which could herself lift 80 tons and she in turn then proceeded to Beira.

These are only two examples of things not going according to plan, but with care 99.9 per cent. of shipments go through without a hitch.

Dangerous Cargoes

Liner vessels are required to carry large quantities of cargo on deck apart from the heavy lifts I have mentioned; hazardous cargo, including acids, low flashpoint spirits, for which there are many special regulations issued by the Ministry of Transport. A knowledge of the "Bluebook" giving the "Recommendations of the Departmental Committee on the Carriage of Dangerous Cargo in Ships" is a "must" for every freight man. Most liner companies have men who specialise in what is known as "dirty" cargo. The regulations which were issued last year should be studied by all industrialists, manufacturers and shippers who deal in any cargo which might be described as hazardous.

Frequently vessels already laden with general cargo proceed to special loading anchorages to load explosives. In South Wales, Milford Haven provides an anchorage (probably the safest in the United Kingdom) to which many ships proceed for explosives after leaving Birkenhead. Vessels with explosives on board are precluded from entering certain ports, and at others there are very stringent regulations imposed.

Certain commodities which require special stowage, are not so much dangerous as objectionable, as they could cause damage to other cargo or give rise to "tainting." For example, large consignments of creosote are accepted, usually in 40-gallon drums. The ideal packing of creosote is in new sound steel drums, but these are expensive and not always easy to obtain. Therefore, most manufacturers use secondhand drums. When these arrive at the dock they are carefully examined and those obviously unsuitable are returned to senders. The remainder of the consignment is left standing in the open for a couple of days before loading so that any leakage may become apparent. A few more are then returned to the sender. By the time they are stowed in the lower hold of the carrying steamer it is possible that one or two more may be on the point of commencing to "weep." Therefore, drums of creosote are not stowed in refrigerated compartments, as any leakage might damage the insulation. This also applies to such substances as tar and bitumen; in fact, most companies prefer to keep out of the refrigerated holds such cargo as steel railways sleepers because they are normally treated with a bitumen or creosote finish, which is "tacky" and smells.

Mirbane Oil (Nitrobenzene) is another substance which we carry on deck only, although Ministry regulations permit it below. We insist on deck stowage not so much on account of its danger but because a mere cupful of it leaking into a ship's hold would be sufficient to make that compartment unsuitable for tea homewards, until it had been cleaned and deodorised.

Chemical solvents with flashpoints down to zero Fahrenheit are now moving in large quantities—sometimes too much to stow on deck, but special arrangements can be made for these to be stowed below deck (usually No. 1 upper 'tween deck) with ventilators and extractors fitted.

Certain commodities are not allowed in the same ship as explosives; one such is carbon bisulphide. The old "Board of Trade" book stipulated that each package of this cargo stowed on deck must be protected from the direct rays of the sun and inspected at least twice daily to check that there is not the slightest sign of leakage; if a leak is discovered the package would be thrown overboard immediately, the bill of lading having been claused "On deck at shippers' risk," and as if to impress on the chief officer the need for seeing that the inspection was faithfully carried out, the book went on to say that if there were a leak the mere striking together of two pieces of metal up to 20 or 30 feet from the leaking package might cause a spark which could ignite the vapour and flash back to the container. This is not very popular cargo and most shipping companies try to dodge it altogether. Invariably it costs far more to carry than the freight contained, because of specially stringent regulations at various places overseas.

Handling of Cement

Cement in paper bags moves in large consignments, and for which most trades have a standard protective clause. Before the war, cement was mainly shipped in drums or casks or in paper lined hessian sacks. Later, manufacturers switched to five or six ply paper bags, but although these are admirable for inland transport, and adequate for delivering the odd hundredweight or so, no one seriously suggests they are the ideal packing to move say 1,000 tons for seven or eight thousand miles, with loading from the works into barge or wagons, then discharge from wagons, and stowage into the steamer; discharging at port of destination, possibly into shed or overside into lighters, and later reloading on to railway trucks or lorries for conveyance to ultimate up-country destination. But because of the high cost of the alternative forms of packing, shippers prefer to face a claused bill of lading. In some trades it is customary for shippers to ship freight free empty bags up to 4 per cent. of the total number of bags of cement shipped, to be used to slip over the broken bags, or as receptacles into which spillage from other bags can be swept.

Cargo in fibreboard packages gives rise to certain difficulties but the range of commodities accepted without clausing bills of lading has grown considerably, although stowage difficulties are presented by this type of packing. They are much more easily pilfered and cannot stand the weight of more than a few tiers of similar packages.

Perishable cargoes (such as seed potatoes) move in large quantities in their season, and must be stowed so that there is a constant circulation of air amongst the packages and special attention is given to ventilation and adequate dunnage. Nowadays some are moving in fibreboard cartons instead of wooden cases or crates used hitherto, and that increases the difficulty of stowage.

Special safety precautions are in force during the known bad weather periods. In winter months we do not use the starboard side of the fore deck of our ships; thus in the months of December to February inclusive, we limit cargo on the fore deck on outward voyages to what can be stowed on the port side.

The rate of loading and discharging is generally lower than before the war practically all over the world. There have been, and still are, considerable delays in some ports although there has lately been an improvement in most, and particularly in the United Kingdom, but vessels are still spending more days in port than at sea. It is vital that we should speed up the turn-round of our ships, and save days both in loading and discharging. The fear of unemployment in the future, and the lingering memory of it in the past, may cause men to adopt "go slow" methods in an endeavour to stave off the evil day, but management and labour must both surely realise only too well that if it takes more men longer to do a job here than elsewhere, then the job itself will go elsewhere to the detriment of us all.

Efficient and modern methods to speed up cargo handling must be encouraged if British ports are to keep abreast of their competitors.

Oscillations of the Sea and the Phenomenon of Range

Part 1 Coastal Seiches

By B. W. WILSON, M.Sc., C.E. (Illinois), A.M.I.C.E., Assoc.M.ASCE., A.M.(S.A.)I.C.E.

IT is well known to anglers throughout the world that sea-fishing with rod and line from low rocks is at times a dangerous pastime, especially if heavy seas happen to be impinging on a coast. Several consecutive waves may break on a barrier of rocks in a consistently uniform fashion, but the sea may then suddenly flood and swiftly rise several feet above its normal level to swamp the unwary fisherman. A few minutes later it may ebb again mysteriously, exposing weeds and limpets on rocks previously hidden by the tide.

Fishermen are apt to explain this whimsicality of the sea on the basis that every seventh wave is larger than the rest, but few can suggest why this should be. Dr. Forel appears to have been the first to evince any scientific interest in such behaviour of the ocean, largely as a result of his classic researches on the surging of lakes, which so captured the fancy of the scientific world in the latter part of the last century. In 1879, he wrote[1]:

> "What are these oscillations (of the sea) with periods of 5, 10, 20 or 100 minutes, which are sometimes irregular? Are they analogous to our (lake) seiches? ...... provisionally, I shall call them by the name of 'vibrations of the sea.' I venture to invite men of science who live on the sea coast to follow this study. It present a fine subject for research, either in the interpretation of the phenomenon or in the establishment of the relations between these movements and meteorological conditions."

The story of Dr. Forel's pioneering studies on the Swiss lakes has been beautifully told by Sir George Darwin[2]. For a full understanding of the oceanic form of the lake phenomenon it will be necessary to recount some of this story and other facts, to which it is the introduction.

The Phenomenon of Lake Seiches.

It has been known for centuries that the water of Lake Geneva at its terminals rises and falls on occasion, sometimes through a range of 5 or 6 feet at the long, funnel-shaped end of Geneva. That this variation was rhythmic in character seems to have been recorded first by de Duillier, a Swiss engineer, in 1730, who mentions that in his time the movements were known as "*seiches.*" These oscillations were not merely confined to Lake Leman (Geneva) but were common to all lakes, as was pointed out by Vaucher in a memoir of 1803, in which he remarked that their occurrence seemed to be related to the condition of the atmosphere. These facts are recorded by Dr. Forel[3].

Forel commenced his patient observations in 1869 at the harbour of Morges on the Lake of Geneva, using first of all a simple portable instrument called a plemyrameter, which enabled him to detect the rise-and-fall of the pulse-like movement of water. Later he developed a self-registering limnograph with which more factual data were recorded. By 1875 he was able to show that the waters of Lake Leman rocked from end to end in a gigantic mass-movement, of which he exclaims ecstatically[4]:

> "... I feel bound to recognise in the phenomenon of seiches the grandest oscillatory movement which man can study on the face of our globe."

When it is appreciated that the lake of Geneva is some 45 miles long by 10 miles wide near its centre, the significance of a movement in which every particle of water oscillates in perfect synchronism with every other may perhaps be realised. Forel recognised further that the seiche phenomenon in its most elementary form was due, in effect, to two waves, each of a length between crests of twice the length of the lake, travelling simultaneously in opposite directions to each other. The resultant of two such waves is a "standing" wave with the pecularity that it remains fixed in position while still performing the up-and-down movements characteristic of a wave. This standing wave, in the case of the fundamental oscillation in a lake, amounts to an up-and-down movement of water at each end of the lake such that while the water ebbs at one end it floods at the other. Approximately half-way between these extremes the lake-level remains unaltered throughout the full cycle of events while the ends see-saw up and down. The line across the width of the lake at which vertical movements of water are nil is called a ***node***, and the seiche itself is ***uninodal*** through having but one node in the length of the lake.

Forel soon discovered that there were bi-nodal, tri-nodal and other multi-nodal seiches existent usually at the same time. These latter seiches are higher harmonics of the fundamental seiche and are characterised by the fact that their periods are very closely integral submultiples of the period of the fundamental uni-nodal seiche. In addition to this Forel was able to identify the co-existence of systems of longitudinal and transverse seiches.

Forel's discoveries were taken up by numerous followers all over the world, such names as Plantamour, Sarasin, von Cholnoky, Delebecque, du Boys, Lauriol, Gautier and Endrös in Europe, Perkins, Denison, Bell, Dawson and Wheeler in America, and Airy in Britain being connected with the subject in the last quarter of the century. Intensive studies were pursued in the first decade of the present century, but Chrystal and his associates Murray, White, Watson and Wedderburn in Britain probably accomplished more than others towards investigating the dynamical theory underlying the phenomenon and explaining its causation.

The Causes of Seiches in Lakes.

Forel himself was disposed to attribute the development of seiches to various causes such as that of a steady wind heaping the water towards one end of a lake and suddenly ceasing[5], of variations of barometric pressure overlying a lake, of possible disturbances to a lake bed from earth-tremor sources, but, most frequently and likely, of sudden storms or squalls traversing a lake.

As more evidence was amassed it became evident that small fluctuations of barometric pressure were much more important than would have thought possible. Professor Chrystal in fact established that not only were minute variations of atmospheric pressure existent at the same time as seiches, but that mathematically they could be held to account for the phenomena observed. In his own words[6]:

> "Forel and his followers du Boys, von Cholnoky, and others have discussed the causes of seiches; and recently Endrös, in his important memoir on the Chiemsee, has confirmed the conclusions of his predecessors, and added some fresh details of great interest. In what follows we shall not advance anything of great novelty; but there are two points of interest which may be worthy of the reader's notice. In the first place the use of the Dines-Shaw microbarograph enabled us to follow continuously the minute variations of the atmospheric pressure with an ease and certainly hitherto unattainable. Also in an appendix to this memoir the mathematical theory of the effect of pressure disturbances of various kinds on an ideal lake, of form not very remote from Earn, has been worked out so as to show that the usually assigned cause of seiches, viz., the minor local fluctuations of barometric pressure, is in reality sufficient to cause the disturbances observed and is not a negligible quantity on ordinary lakes such as the tidal action of the moon can be shown to be."

Oscillations of the Sea and the Phenomenon of Range—continued

Further on he says:

"Observers are now agreed that the development of seiches usually accompanies local disturbances of the barometric pressure, whose duration if they are transitory, or period if they are periodic, does not differ greatly from the period of the seiche in question. Our observations on Earn bear out this conclusion."

Professor Chrystal in the course of this paper gives many examples of limnograms and microbarograms in testimony of this.

In a critical discussion of all the factors likely to give rise to seiches, Chrystal remarks that they may be sudden or gradual. Sudden generation could be the result of

(1) rapid release of pressure following upon progression of an isobaric system;
(2) sudden release of pent-up water at one end of the lake through lapse of the wind;
(3) heavy rain, snow or hail over portion of the lake;
(4) rapid change of air pressure through passage of a squall;
(5) flood discharge from rivers at one end of the lake;
(6) impacts of wind gusts on the lake surface:

whereas gradual generation could be occasioned by

(7) passage of small barometric fluctuations synchronising approximately with seiche periods;
(8) variations in wind velocity and pressure synchronising closely with seiche periods.

On theoretical grounds Chrystal disposes of factor (1) as being unable to explain ordinary seiches. Factor (2) he accepts if the thesis can be established that water is piled up by the wind: variation of pressure and rain usually accompany wind and it may be hard to discriminate on this point. Factors (3), (4) and (5) are all accepted as causes which can be adduced from observed results. Item (6) he finds hard to prove or disprove, but in its related form (8) it could certainly be a cause. Factor (7), however, he is able to illustrate as being a frequent and obvious stimulant in the production of seiches.

As Chrystal's work is in large measure a summing up of all the evidence extant at the time, including his own extensive observations and measurements, we may reasonably accept his conclusions, already quoted as being the correct explanation of the seiche phenomenon in the great majority of cases.

Professor Chrystal, however, makes no mention in this discussion of causative factors, of the possibility of seismic origins for seiches, although in an earlier paper[7] he cites the fact that on the occasion of the great earthquake at Lisbon, on November 1st, 1755, remarkable seiches developed in Loch Lomond, Loch Long, Loch Katrine and Loch Ness, according to descriptions in the Scot's Magazine of that year. Further fascinating accounts of similar repercussions in England and Europe are recorded in the Gentleman's Magazine for 1755, which have a bearing on this question.

Although it is difficult at this time to know where the epicentre of that earthquake was, we must presume that it was within the vicinity of Lisbon, probably near St. Ubes (Setubal) for the captain of a Dutch vessel saw the mountain about 6 or 7 leagues from St. Ubes rend and fall into the sea about 9.45 a.m. The great catastrophe at Lisbon is variously reported as having occurred at about 9.30, 9.57 and 9.50 a.m., but at Cadiz, 200 miles distant, the shock was felt at about 9.56, and at Oporto, 190 miles away, at about 9.40 a.m. The earthquake was felt in Madrid at 10.20 (315 miles distant) and at Gibraltar at 10.10 a.m. (265 miles away). At Cork, in Ireland, shocks were felt at 9.30 a.m., and reports indicate that the earthquake was felt in Milan and Scandinavia. According to Professor Chrystal the Scot's Magazine records that the seiches in the Scottish lakes developed between 9.30 and 10.15 a.m. and at Loch Lomond a rumbling sound was heard which suggests that the highlands received a full tremor. If we allow for the confusion prevailing at the time and the fact that shocks are reported to have lasted from 10 to 15 minutes at first, although they were repeated later in the day, we may consider the earthquake to have occurred at about 9.45 a.m.

Since earthquake waves travel with incredible speed, at an average perhaps of 10,000 m.p.h. in the crustal regions of the earth, it would have taken only a few minutes for the disturbance to make itself felt in the Scottish highlands and it is a reasonable deduction therefore that the loch seiches were genuinely caused by the vibration of the lake-beds.

But in the lowlands of England and other European countries seiches also developed in large ponds, canals and enclosed waters without any vibration of the earth being perceptible, and as their times of occurrence were much later than would be in keeping with shock-transmission through the earth, we are led to enquire whether their origin can be ascribed to pressure-waves in the atmosphere. The noise of the earthquake at Lisbon and the several accounts given of the earth opening and emitting clouds of smoke, dust and fumes would suggest the creation of air-waves[8], but proof positive of their existence in great strength is afforded by the following account from a correspondent in Leyden (Nov. 4, 1755):

"On Saturday last, in the forenoon, the water in the several rivers, canals, and lakes, was agitated to such a violent degree, that at Woubrugge, Alphen, Boshoop, and Rotterdam, buoys were broken from their chains, large vessels snapped their cables, smaller ones were thrown out of the water on the land, and others lying on the land were set afloat. In the lake of Harlem particularly, the course of a vessel under full sail was suddenly suspended and the rudder unhung. No motion on land, of the houses and buildings was felt. During the time of this agitation, which continued near four minutes, not only the water in the rivers and lakes, but also all manner of fluids in smaller quantities, as in coolers, tubs, buckets, etc., was equally agitated, and dashed over the sides, notwithstanding no motion was perceptible in the containing vessels. In such small quantities also, the surface of the water had apparently a direct ascent, prior to its turbulent motion, and, in many places, even the rivers and canals rose 12 inches perpendicular. It is asserted also from Amsterdam, that, *during this interval, the mercury in the barometer, which about this time was uncommonly high, decended instantly near two inches, and made several subsequent vibrations.* (writer's italics)

It is quite obvious that nothing but a series of air pressure-waves could have caused the barometer to have behaved in this fashion, and their existence at once explains the seiche-phenomena described, in terms of Professor Chrystal's findings on fluctuations of barometric pressure. Further confirmation of the seiche-like behaviour of enclosed waters is given in a letter from Amsterdam (Nov. 7, 1755):

"The late extraordinary agitation of the water extended beyond Utrecht, and also southward to Brabant; where in the district of Hertogenbosch, it lasted near half an hour, occasioning wrecks of vessels, long since sunk, to rise to the surface and float for several minutes, notwithstanding there was not the least wind, nor any motion discovered in the land.

"At Lübeck in Holstein, the water in the Trave rose four or five feet perpendicular in an instant, by which motion the ship of Capt. Panders snapped its cables, and great damage was done to other vessels. The agitation of the waters is said to have lasted nine minutes; and it appears everywhere, indeed, to have lasted proportionable to the height of the instantaneous ascent. From Gluckstad and other places there are also similar accounts, all agreeing that not the least motion was observable on the land.

"And letters from Brussels mention that it was felt very sensibly through the whole course of the rivers Weser and Elbe."

Additional evidence for an air-pressure origin of these remarkable occurrences is furnished by accounts of what took place in England. A letter from Portsmouth, dated Nov. 3, 1755, says:

"On Saturday last (Nov. 1st) His Majesty's ship Golport was carried into the dock to be cleaned, about half an hour past ten in the morning she was observed to pitch forward with her head deep in the water and immediately to recover it and pitch as deep in with her stern; the water about her was greatly agitated, and the dock gates forced open about six inches.

"At a very considerable distance is a large basin, which has not the least communication with this dock, and in it are the Berwick, Nassau, Dover, and another large ship; these at the same instant felt the shock, but instead of pitching they rolled very violently; none of those who were on the land could perceive the earth either under or about them to move."

Oscillations of the Sea and the Phenomenon of Range—continued

The direct distance from Lisbon to Portsmouth along a great circle is about 975 miles, and if the air waves are presumed to have travelled at 780 m.p.h. (the theoretical speed of sound in air at 80°F.), they would have passed over Portsmouth about $1\frac{1}{4}$ hours after occurrence of the earthquake, that is, at about 11.0 a.m., which within the limits of error is in good agreement with the time of the incident quoted above. At Cranbrook, Horsmonden and Tenterden in Kent, some 20 to 30 miles north of Portsmouth, agitation of water in dams and ponds is described as having occurred between 10 and 11 in the morning in similar circumstances; while at Finchingfield, Essex, and Barlborough, Derby, respectively 1075 and 1145 miles from Lisbon as the crow flies, seiches in ponds are recorded as having occurred between 11 and 12 a.m. Over these greater distances, in the latter two instances, the air waves would have taken respectively 1.38 and 1.47 hours, making the times of arrival 11.08 and 11.13 a.m., which again are seen to be in good agreement with the observations. Had these disturbances been caused by direct earth-tremors they would have developed between 9.30 and 10.0 a.m. as did the seiches in the Scottish lochs and it is almost certain that ground vibration would have been felt. The remarkable circumstance that the terrestrial shock-waves penetrated into the highlands over a wide field, but failed to disturb the intervening lowlands is a problem we must leave for the geophysicists, but, on the evidence, one is impelled to the conclusion that concussion-waves in the atmosphere arising from the great earthquake must have been of a periodicity sufficiently close to the seiche-periods of a large number of bodies of water to impress upon them the extraordinary oscillations described.

Sea-oscillations of Seismic Origin.

Long before Forel commenced his researches on seiches in lakes, it had of course been a matter of common observation that bays and estuaries fronting on the sea were sometimes subjected to extraordinary convulsions from huge waves. In a small way these conditions were no different from the great tidal waves (the true tides) that sweep up many coastal inlets such as the Bay of Fundy, the Severn Estuary, and Hangchow Bay, to mention but a few, but because they were unusual and unexpected they were always dangerous.

The great earthquake of Lisbon generated big sea-waves of this kind, and as their effects were peculiar to many of the harbours which they overwhelmed, it is of some interest to our argument to consider the accounts of them given in the Gentleman's Magazine of 1755.

Lisbon lies on the north bank of the considerable estuary of the river Tagus, which with its comparatively narrow mouth is virtually an enclosed piece of water. Into this rushed the sea-waves that followed sometime after the earthquake and

> " . . . . whilst the multitude were gathered near the riverside, the water rose to such a height that it overcame and overflowed the lower part of the city. . . . ."

This is the account of a captain of a British vessel, which was anchored in the estuary, who had previously felt the earthquake itself as a shock suggestive of the ship having fouled the river bottom. He records further:

> " . . . . boats were carried away by the retiring sea, which ebbed and flowed, ebbed and flowed in four or five minutes . . . and the tide so quick eastward and westward, that the ships turning fast round, ran foul of each other . . . . I observed the Sea at the Bar break feather white as if agitated by a storm . . . . By my best judgment the water rose in five minutes about 16 feet, and fell in the same time for three times, and at two the tide returned to its natural course."

All this suggests that the sea-waves had a period approximating 10 minutes.

The sea-waves bore down upon Oporto, Cadiz and Gibraltar and indeed upon the whole coastline in the neighbourhood. A correspondent writing from Oporto records that the earthquake shock was felt at about 20 minutes before ten in the morning. Only a few minutes before starting his letter he mentions that another concussion was felt a 11.20 a.m. Obviously at that time the sea-waves had not arrived, for he says:

> " The ship this goes by sails tomorrow morning, so shall defer concluding till near time she sails."

He continued his letter the following morning, and recounts that a further shock was felt at about noon of the previous day, to which he apparently ascribed the remarkable effects on the river:

> " . . . . the tide rose considerably higher than was ever known, except in case of a flood; and the flux and reflux was so sudden, that in a minute or two it rose and fell five or six feet, and continued so for two or three hours; this I was witness to."

In reality, of course, this commotion was being caused by the arrival of the sea-waves generated at 9.45 a.m. by the main earthquake disturbance.

At Cadiz the earthquake was also felt at about 9.45 a.m., but according to another corresondent,

> " An hour afterwards the sea was calm, not a breath of air, but prodigious close and warm; on a sudden the sea swell'd up (without the least wind) all round the city . . . ."

Similar effects were felt at Gibraltar, where:

> " The sea rose six feet every 15 minutes, and fell so low that boats . . . were left aground . . . .This flux and reflux lasted till next morning, having decreased gradually from two in the afternoon."

The seismic sea-waves, fanning out from their epicentric origin, raced towards the southern coasts of Ireland and England. At Kinsale, in Ireland, it was reported on the day of the earthquake that

> ". . . . in the afternoon, when the tide had ebbed some time, it suddenly returned with a violence and impetuosity impossible to describe . . . These sudden and surprising fluxes and refluxes of the sea continued from three in the afternoon till ten at night, seldom more than a quarter of an hour between each return."

From Swansea, Wales, came another report to the effect that on

> " The 1st inst. about three quarters past six in the evening, a mile and a half up river, after two hours ebb, a large head of water rushed up with a great noise . . . . It fell almost as suddenly, for in 10 minutes there was no appearance left of more water than usual at that time of tide . . . . A vessel arrived since from Hayle in Cornwall brings an account, that the same day, about four in the afternoon, they had three heads of water, one after the other . . . ."

From these accounts and the knowledge we now possess of the speeds of long waves in different depths of water, it is certain that these various effects had a common origin at the time and place of the great earthquake, probably close to Setubal on the submarine escarpment that connects with the island of Madeira. (The writer has checked this by calculation, using the equation $c = \sqrt{gd}$, for the wave-velocity c in the depth d of water). It is significant that off Cornwall three " heads " of water were experienced, agreeing precisely with the three main waves reported in the estuary of Lisbon itself. Only one head of water rushed up the Neath river at Swansea, and presumably this is because the waves merged in the shoaling waters of that estuary. It is worthy of note that at both Kinsale and Gibraltar the periodicity of the waves was 15 minutes, and at Lisbon 10 minutes, while at Cadiz it would seem to have been about 5 minutes. These differences are not impossible owing to a certain amount of occlusion of the main periodicities from seiche-like effects peculiar to the bays and estuaries where the observations were made.

An important point that arises from the examination of this case is that the disturbances in the various bays and inlets continued for long hours after the arrival of the seismic sea-waves, and while the reason for this could possibly in this instance be imputed to subsequent minor shocks, we shall advance the suggestion, on the basis of further evidence to be revealed in due course, that the explanation for it is to be found in the pseudo-seiches which were created by trains of following waves and by the initial disturbances themselves.

There have been many earthquakes in history which have produced seismic sea-waves of great destructive power, but probably none so widespread in its effects as the great eruption of Krakatoa in 1883, which saw the virtual disappearance of that island in the Sunda Strait between Java and Sumatra. Inasmuch as the sea-

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waves from this gigantic molar disturbance penetrated scores of bays and harbours as far afield as the North Atlantic and the Eastern Pacific, consideration of their effects has special interest.

The great sea-waves which were generated by the convulsions of Krakatoa were some 60 feet high at their origin and had a periodicity of approximately two hours with a distance between crests of the order of 80 miles[9]. Their progression through the Sunda strait on August 26th and 27th, 1883, seems to have induced second harmonics, with the result that the waves were propagated across the oceans at intervals of about an hour apart. Wave-trains of shorter periodicities were observed by various witnesses so that it is probable that a rather mixed assortment emanated from the disturbance.

These wave-trains produced remarkable embroideries on the marigrams of tide-gauges at Colombo, Vizagapatam, Ceylon, Mauritius, Port Elizabeth, Cape Town, Honolulu, San Francisco and many other ports, but the significant thing is that the prominent periodicities which were excited in these harbours were often widely different. At Mauritius, for instance, the main periodicity was between 30 and 40 minutes, whereas at Mahe, in the Seychelles, it was 21 minutes; at Honolulu the period was 30 minutes, while in San Francisco Bay the conspicuous periods were 24, 34 and 47 minutes. The disturbances reached Table Bay some 14 to 15 hours after the final paroxysm of Krakatoa and revealed themselves as undulations about 18 inches high and of about 62 minutes' period with overlying oscillations of about 10 minutes' periodicity. At Port Alfred and Port Elizabeth oscillations of from 10 to 20 minutes were particularly pronounced.

The evidence is manifold that the various gulfs, bays and armlets of the sea were responding to particular frequencies of waves which corresponded to their natural shape and depth. As with the Lisbon earthquake the vibrations continued for hours and even days after their commencement.

One further example of seismic sea-waves may be considered as having the special value of recency in our time: this arose on April 1st, 1946, from a submarine earthquake whose epicentre was in 9,000 feet of water at 163°W long., 53½°N lat. in the Aleutian Trench. The waves were recorded on arrival at 15 tide-station of the United States Coast and Geodetic Survey, and at points on the coasts of British Columbia, Costa Rica, Peru and Chile. A full report of this interesting occurrence was prepared by the United States Coast and Geodetic Survey[10] from which we reproduce in Fig. 1 a typical marigram for Clayoquot, British Columbia, illustrating very clearly the sudden arrival of the forced waves and the development thereafter of parasitic oscillations, attenuating slowly over a long period.

It was found from the many such records that the average periodicity of the sea-waves was 15.6 minutes, a value which lends some credence to the belief that the Lisbon earthquake must have

Reproduced from Report of U.S. Coast & Geodetic Survey, 1946.

Fig. 1. Seismic Sea Wave. Tide Gauge Record for Earthquake of April 1st, 1906. Clayoquot, British Columbia.

generated very similar waves. The marigrams reproduced in this report leave no doubt of the fact that bays and inlets of the sea are subject to the same kind of oscillations as inland lakes and that seismic sea-waves are at least one cause of excitation.

Coastal Seiches of Meteorological Origin.

If seismic sea-waves are responsible for the most spectacular and cataclysmic effects along the coastlines of the world, they are certainly not the most frequent: hurricanes and cyclones are a far more prolific source of devastating seas, and very often they give rise to a mass-transport of water through combination of intense wind and barometric suction. For the present, however, we shall defer consideration of these exceptionally violent effects to discuss more fully the phenomenon of coastal seiches.

The sea-oscillations we have noted as occurring in bays and inlets do not necessarily require violence for their generation. Airy's attention was drawn to peculiar fluctuations of the tide at Malta which were quite appreciable in the years 1871 and 1872[11]. They occurred usually in a tranquil sea, as simple-harmonic variations of great regularity with a periodicity of about 21 minutes and a vertical range of some 12 inches. Having just heard of Forel's investigations on the Lake of Geneva, Airy at once concluded that the phenomenon was similar to the lake-seiches, and he conceived the seiches at Malta to be the result of wave reflections between the shores of Sicily and Africa. In reality the seiches must have been peculiar to the single small bight in the coastline of Malta where the tides were measured. Airy makes the interesting comment that seiches with intervals of 15 or 20 minutes had also been registered at Swansea, in Wales.

Darwin[12] also had noticed in the trace of the tide-gauge at Bombay irregularities with periods ranging from a few minutes to over quarter of an hour, and while not subscribing immediately to the view that they were seiches, he recognised their affinity, and, in common with Forel, was content to call them vibrations of the sea. Numerous other investigators took up the study of what were then currently called the "Secondary Undulations" of the tides, Duff and Denison in Canada, Russell in Australia, and Plantania in Italy being prominently connected with the subject at the turn of the century. These investigators all came to the conclusion that the effects observed were connected with barometric disturbances over the ocean.

Between 1903 and 1908 the phenomenon was very intensively studied by Professor Omori and his associates Honda, Terada and Isitani in Japan as a part-undertaking of the Japanese Earthquake Investigation Committee[13]. After measurements of some 60 bays of the Japanese islands they showed conclusively that the secondary oscillations depended for their periodicity upon the configuration of the coastline, and that the periodicity could even be calculated with fair approximation from the basic dimensions of the bay, on the supposition that the oscillation partook of the nature of a uninodal seiche with the node at the mouth of the bay. They attributed the secondary undulations of long waves generated by fluctuations of barometric pressure, wind or earthquakes in the open ocean, confirming thereby the deductions of previous investigators.

Professor Chrystal in his concluding report (1908) on the seiches in the Scottish lakes, refers to the corresponding sea-phenomenon by remarking[14]:

> "These oscillations (in bays) which are sometimes of considerable range, are apparently due to resonance with comparatively inconspicuous undulations in the external oceanic swell, the periods of which are equal to some of the natural periods of the bay."

and Darwin, in the later edition of his book (1910), comments:

> "It now seems to be well established that landlocked arms of the sea and bays have their regular seiche-like oscillations . . . The vibrations are almost certainly produced by differences of barometric pressure, but the periods of oscillation must be determined almost entirely by the configuration of the inlet . . . ."

From this stage onward the mathematicians picked up the threads and by applying Chrystal's work to bays were able to explain most of the peculiar oscillations occurring: Harris in

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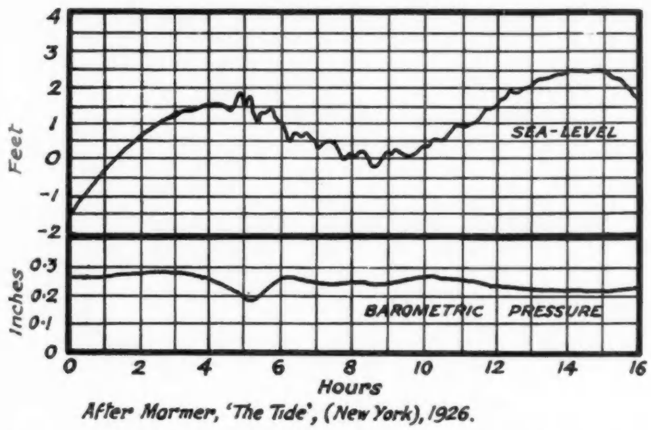

Fig. 2. Seiches in San Francisco Bay, developing from a Barometric Pressure Fluctuation, Nov. 21st, 1910. (Mean Velocity of Wind 5 m.p.h. Maximum 10 m.p.h.)

America (1908), Proudman (1914), Doodson (1920), Goldsbrough (1930), and Lamb (1932) in Britain, and Defant in Europe (1929) were prominent in this field. Marmer (1926)[15] gives us quite an up-to-date explanation of the phenomenon (in generalised terms) in the following:

"The exciting cause of the seiche may be sudden changes in barometric pressure, strong winds, or waves from the sea. In the open sea waves of various periods appear to exist and as these proceed towards the coast the one whose period approximates to the period of the body of water opening into the sea will bring about a seiche in that body of water.

"Seiches occur most frequently in deep bays or estuaries that are nearly landlocked. But they may also be found in any portion of the sea partly bounded by land, for any such area is capable of sustaining stationary wave oscillations of a period conditions by its length and depth."

An interesting example of seiches generated in San Francisco Bay by barometric depression on November 21, 1910, is reproduced from Marmer in Fig. 2 as demonstrable proof of this mode of excitation. The predominant oscillations in this marigram have a period of about 48 minutes, but there is also evidence of a secondary 17 minute periodicity. From observations and model experiments, San Francisco Bay has now been shown to have several distinct modes of oscillation yielding periodicities of 17-19, 24-27, 34-41, 47 and 116 minutes[16], which become prominent according to the circumstances of the disturbing agency.

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(to be continued)

British Inland Waterways

Review of Policy Since Nationalisation*

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The inland waterways have been much in the public eye and ear during the last few years. They have formed the subject of films, of broadcasts by sound and television, of discussions in lecture rooms and not infrequently in Parliament, and of many books and Press articles. The evident interest of a considerable section of the public is gratifying to those responsible for or employed in the industry, even if much that is published seems to be inspired more by regret for the past than by practical ideas for the future.

The purpose of this article is not to dwell on the past or to pass judgment on it, nor is it to lament the conditions which the Executive inherited in 1948. Its object is to explain the policy which has been followed since then and to express some views on the part the waterways can continue to play in the life of the country. In so far, therefore, as the past is recalled, it is for the purpose of illustrating inherited and inherent aptitudes or disabilities.

The railway companies certainly played their part in destroying, actively or by neglect, the trade of the waterways; but there were other factors at work. The canals, designed as they were to meet essentially local needs, inevitably came into being in a piecemeal way. The objective was not a national or even an extensively distributed transport system but a service for specific commodities between strictly defined points. The result was a series of undertakings of widely diverse widths and depths of water and widths and lengths of locks, so that the canals which link great industrial centres often vary extensively in respect of the dimensions of craft by which they can be used. These limitations upon through transit naturally impose a heavy handicap on the economic use of carrying craft. Imagine the railways with a dozen or more different gauges! It is not surprising that the fast-developing industry of the last century turned to a new, more ubiquitous and more flexible form of transport. The advent and development of the internal combustion engine it its turn, and for the same reasons, extensively impinged on the traffic of the railways and further emphasised the comparative inaccessibility of the canals. Other causes of decline were that in the course of time many of the coal mines and industries to serve which canals had been constructed went out of production or shifted their works, leaving the canals without their trading connections. In colliery areas, too, canals suffered severely from mining subsidence, which brought them down in the general ruin of the areas subjected to this form of devastation.

The proprietors of many canals were glad to sell out to the railways, or found it more profitable to live on the proceeds of their estates than to spend money in maintaining or developing their canals. Even so, the remaining canals continued to carry a substantial, though gradually diminishing, tonnage up to the date of nationalisation.

The first practical step towards arresting the decline of the canals was taken when the Transport Act 1947 put into effect the long advocated policy of unification of the undertakings under one authority. With a few exceptions (the Manchester Ship Canal, the Bridgewater Canal and the River Thames being the most important), the country's inland waterways were transferred to the British Transport Commission who delegated their administration to the Docks and Inland Waterways Executive. This association of the waterways with docks was not, as some have thought, capricious or just a marriage of convenience. Waterways lead naturally to the sea, and where they meet it in estuaries are our principal ports. Moreover, the technical problems of docks and waterways have

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British Inland Waterways—continued

much in common and lend themselves, in combination, to an engineering organisation with wide but related fields of operation and experience.

The first tasks of the Executive were the creation of administrative groups of waterways under decentralised managements but single control, the strengthening of the engineering, commercial and financial machinery, and the making good of the arrears of maintenance due to long years of neglect or to more recent exigencies of war-time. The steps taken have been stated in the annual reports of the British Transport Commission and I shall not recapitulate them here. Altogether some £7 million has been spent on maintenance of the Executive's waterways and waterways craft in the last five years. As a result they are as a whole in much better heart and condition than when taken over, and are carrying more traffic.

Obviously neither the national situation nor that of the Commission allowed of indiscriminate or unlimited expenditure of money, labour or materials, and it was immediately necessary to select those sections of the waterways where expenditure would be most profitable and to concentrate it as far as possible upon them. I say "as far as possible" because even an unused canal cannot be wholly neglected.

Investigation of trading conditions and prospects has indicated that of the existing 2,000 miles of inland waterways controlled by the Executive about 1,200 miles carry 98 per cent. of the tonnage of freight traffic. These constitute an effective national system connecting the industrial areas and the ports and on them the future of inland waterway freight transport depends. Their principal traffics are—and are likely to remain—goods received or discharged overside in the ports; coal from water-served collieries to bulk consumers, such as power stations and gas works, also situated on the waterways, or to ports for shipment; and the growing quantities of petroleum products conveyed in tank barges to inland oil depots. The encouragement of these traffics must be the primary objective of capital expenditure, which has been directed accordingly. Hence the substantial improvements on the Severn and Trent Navigations, designed to facilitate the movement of larger craft upon them and the establishment of distributing centres on their banks.

The function of the narrow canals connecting the broader waterways with the Midlands will be largely to act as feeders to and forwarders from the broader waterways, though they have in addition a substantial tonnage of local and mainly short-distance traffic in coal and miscellaneous merchandise arising on their banks. They should maintain, and in some directions expand, their business, provided that they can be adapted to the current conditions and requirements of the industries they can best serve and can hold their own in competition with railway and road haulage. To do this costs of maintenance—by far the biggest item of expenditure—must be kept as low as is consistent with efficiency, and the waterway carriers must be able to quote competitive rates. Maintenance costs have risen, not only in sympathy with the general rise in wages and materials, but also from the erosive effects of mechanical transport which has now generally superseded horse towage and has necessitated additional dredging and bank protection. Research is being used to find cheaper and more effective means of maintenance and of efficient carriage in terms of operating costs, pay-load capacity, motive power, design of craft, and handling at terminal or transhipment points.

On the remaining 800 miles of the Executive's system traffic has either ceased or is very slight and is unlikely in any circumstances to revive. This ranges from canals which are still capable of carrying traffic, if it were offered, to sections where past neglect has combined with nature to reduce the physical conditions to those of a ditch. The latter no longer justify the heavy expenditure which would be involved in restoring them: they should be written off as unnnecessary and the space they occupy devoted to other uses. There are, however, many miles of waterway which, though they will never again be used commercially to any extent, can and should be preserved as national assets for one or more of the following purposes, viz., as necessary parts of the land drainage system, or as sources of industrial or agricultural water supply, or as amenities for the enjoyment of those who would indulge in the pleasures of inland boating and fishing or waterside walking. These purposes can be combined, so that waterways no longer required for their original ends may be converted to other uses. This desirable objective is not, however, to be assisted by indiscriminate demands for the retention, at great expense and to little or no purpose, of every bit of so-called canal.

The recreational value of canals is increasingly recognised and we gladly encourage this healthy tendency in many practical ways. Last year well over 4,000 permits were issued for pleasure boating and cruising. The awakening realisation that scenic beauty and the opportunities for enjoying it are not only a national asset but a national necessity should, and I believe will, embrace many miles of our commercially deserted canals and insist on their preservation. Whether the cost of their maintenance should be, as it is to-day, a charge on the commercial transport system is another question.

Here it may be observed that while the earnings of the commercially active waterways, the 1,200 miles already mentioned, taken as a whole more than cover the costs of their maintenance and operation, the net revenue they are earning is more than offset by the dead loss involved in maintaining the 800 miles of unused or little-used canals. Thus the system as a whole incurs a deficiency. Freed from the burden of carrying the commercially "dead wood," I believe that the active waterways can continue to afford valuable service to the trading community, and that by seeking out and exploiting the traffics for which they can satisfactorily cater they can become at least self-supporting financially.

Recognition of one's physical limitations is not defeatism or timidity. No one regards a sprinter as a pessimist because he does not fancy himself for a marathon. Similarly, all transport is becoming more and more a matter of specialisation. Each method of moving traffic has its capacities and its advantages, particular traffics for which and conditions in which it is especially efficient, convenient and economical. By concentration on these in each case the best combination will emerge, and that should include a significant, if relatively minor, role for inland waterways.

Port of London Improvement Works

New Berth at Tilbury Docks

The Port of London Authority have authorised the carrying out of certain improvement works on the North Side of the Main Dock, Tilbury Docks, to provide suitable additional accommodation for the larger vessels of the Peninsular and Oriental Steam Navigation Co., and the Orient Steam Navigation Co., Ltd. The total scheme which it is proposed shall be undertaken in two stages under separate contracts is estimated to cost in the region of £1,500,000.

The first contract provides for the demolition and removal of the war-time "Pluto" installations; the demolition of No. 1 Shed and part of No. 2 Shed and the existing quay wall at No. 1 Shed in order to widen the Main Dock to 900-ft. and facilitate access for larger vessels to berths on the East side of the West Branch Dock; the construction of a monolith quay wall 843-ft. long having a depth of water alongside of 42-ft. 6-in. below T.H.W., and a return section of wall 240-ft. long which will form the Southern end of the quay of a future branch dock.

The quay will be built on monoliths 30-ft. square with four wells, reinforced concrete shoes and mass concrete walls. After sinking the monoliths will be sealed at the bottom and the back wells filled with concrete. The monoliths will be from 50 to 60-ft. deep and founded on gravel. The spaces between the monoliths will be sealed with reinforced concrete piles.

The quay superstructure will be carried on reinforced concrete beams resting on the monoliths. A service subway will be provided in the mass concrete cope. The quay will have two railway tracks and an 18-ft. gauge crane track to carry 3-ton electric cranes. An earth embankment is to be formed at the west end of the new quay.

As a result of tenders invited for this contract, the Authority have accepted the quotation of Messrs. Holloway Bros. (London), Ltd., to undertake the work. In addition it will be necessary to carry out extensive dredging operations.

The second stage of the scheme provides for the construction of a "T" shaped single-storey transit shed, the main portion being 550-ft. in length at the head and 120-ft. wide, cargo loading and railway passenger platforms, roads and railways. It is anticipated that the scheme will be completed by the end of 1955.

The Corrosion of Iron and Steel and its Prevention

With Special Reference to Harbour and Dock Installations

By J. C. HUDSON, D.Sc., D.I.C., A.R.C.S., F.I.M.
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1. Introduction

IN the last issue Mr. N. N. B. Ordman has dealt with some of the practical corrosion problems that beset dock and harbour engineers. There is no doubt that these can be greatly alleviated, if not removed entirely, by the application of existing knowledge of preventing corrosion. The present author, therefore, regards it as his task to endeavour to set out as clearly and simply as possible the principles governing corrosion and its prevention, which now rest on a considerable volume of research and practical experience. He will do so with special reference to iron and steel, partly because his own researches have been particularly concerned with these but also because these are the most important materials used for general engineering purposes. Clearly, he is not qualified to lay down hard and fast rules for the treatment of individual cases; nor is it his function to decide what outlay on protective measures may be justified for a particular installation. Such decisions must be left to those with practical experience of the operating conditions and to those responsible for financial policy. On the other hand, he hopes that what he writes may provide useful information on which to base these decisions and help those concerned to reach the right ones.

The subject will be considered under three main heads. First, a brief but necessary summary of corrosion theory will be given,* then a statement of what is known about the corrosion of bare ferrous metals under the conditions encountered in docks and harbours, and finally a short survey of the available methods for preventing this corrosion.

2. Corrosion Theory

2.1 General.

The first point to be grasped is that there is nothing unnatural about corrosion. It is just as natural for iron to rust as for water to run downhill. Most of the heavy metals used in engineering occur on the earth in the form of ores. These are in the main oxides or hydroxides of the metals. For example, two of the most

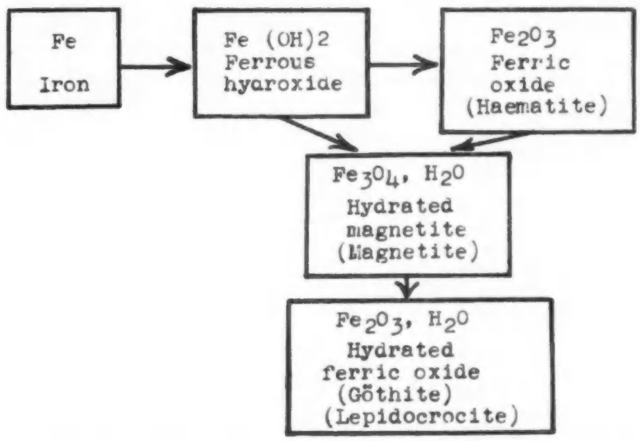

Fig. 1. The Mechanism of Atmospheric Rusting (After A. Girard).

important iron ores are haematite and magnetite, both of which are oxides of iron. When the ores are smelted in the blast furnace with coke and limestone, the oxygen is forcibly removed from them and the iron is set free. Throughout its subsequent existence this iron strives to recombine with the oxygen from which it has been separated. Plenty of air is at hand in the atmosphere for the purpose. Consequently, we find that when the iron or steel billet is heated at the rolling mill it combines with the oxygen of the air to form iron oxides, or millscale, which, as we shall see, is one cause of corrosion troubles. Later in its life, as a manufactured article, the iron continues the process of reversion to the ore by rusting at the slightest provocation. In other words, the ore and not the metal is the stable body, and rusting represents the natural tendency for the iron to revert from the unstable to the stable condition.

The chemical changes involved have been studied by several investigators and, although some details remain to be settled, they

*Some of the points considered in this section have already been mentioned in a previous article by Mr. H. F. Cornick, which appeared in the January and February 1953 issues, but for the sake of completeness it may be helpful to reiterate them here.

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are adequately represented by the reactions given in Fig. 1, which is based on the views of A. Girard (1933).

The rusting process is thus essentially one of oxidation and the transition from each stage to the succeeding one is brought about by the intervention of oxygen and/or water. Natural iron ores corresponding to the corrosion products are shown in brackets; some of these, e.g. göthite, occur in atmospheric rust. The primary reaction is the decomposition of water by iron to form ferrous hydroxide and hydrogen; this can proceed directly under certain special circumstances in the laboratory but as a general rule it is also necessary for oxygen to be present, so that the hydrogen liberated can be oxidised to water at the instant it is formed.

It is unnecessary to dwell on the other aspects of these reactions. The main points to be apprehended are that oxygen and moisture are essential to the rusting process and that the familiar rust formed on iron and steel is a complicated mixture of oxides and hydroxides of iron, some of which are loosely combined with water.

2.2. Atmospheric Corrosion.

For practical purposes both the tendency to rust and the rate at which rusting proceeds once it has begun are of great importance. It has long been known that the severity of rusting varies considerably for the same material when exposed in different climates and various reasons were advanced for this. For example, it was once thought—wrongly—that rusting was caused by the carbon dioxide content of the air. It was left to a British scientist, W. H. J. Vernon, to demonstrate by a series of brilliant researches conducted at the Chemical Research Laboratory from about 1930 onwards that the relative humidity of the atmosphere, controls the tendency to rust and that the velocity of rusting is determined by the degree of pollution of the atmosphere, notably by oxides of sulphur, derived from the combustion of fuel, and solid particles, such as dust.

The essential results of Vernon's experiments are depicted in Fig. 2. He took specimens of bright steel and exposed them to the air inside large glass vessels. Starting with dry air, he progressively increased the humidity of the air at appropriate intervals and determined the amount of rusting of the steel by measuring its increase in weight. Three series of experiments were made: (A) in pure air; (B) in air containing 0.01 per cent. of sulphur dioxide; and (C) in the same atmosphere as (B) but using specimens whose surfaces had been partially covered with small particles of charcoal

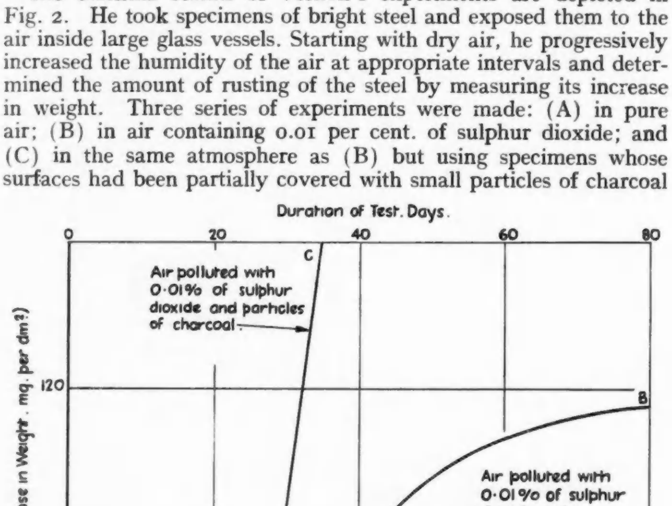

Fig. 2. Effect of Sulphur Dioxide and Solid Impurities on the Atmospheric Corrosion of Iron (W. H. J. Vernon).

or other substances before exposure, so as to imitate the effects of the grime and dust present in most outdoor atmospheres. It will be seen that if the air was pure little rusting took place, even when the humidity approached saturation. In impure air containing sulphur dioxide the attack on the steel was negligible at low humidities, but, when a threshold humidity of about 70 per cent. was reached, rusting became perceptible and, when the humidity rose above 80 per cent., it became severe. The presence of solid particles on the surface of the steel in addition to the sulphur dioxide contamination of the air made corrosion even more intense, but here again only when the humidity exceeded the threshold value.

The two main conclusions to be drawn from this investigation are, therefore:

(1) Iron or steel does not rust appreciably in pure air, whether dry or humid.

(2) When the air is polluted with sulphur dioxide, which we may regard as representing the sulphur compounds discharged into the atmosphere from chimneys, the relative humidity of the air determines whether pronounced rusting will occur or not. The dividing line between severe rusting and comparative immunity from it may be drawn at 70—80 per cent. relative humidity.

As we shall see in section 3.1, these theoretical deductions of Vernon have been fully confirmed by the results of practical corrosion tests in numerous parts of the world. The conception of a "critical humidity," which determines whether corrosion occurs or not, has proved a valuable addition to corrosion theory. It is probable that the value of the critical humidity is not the same for all metals. For example, in some early tests by the author, in which twelve different non-ferrous metals were exposed under sheltered conditions outdoors, the condensation of moisture from the atmosphere was observed to occur more readily on some metals than on others. Under these conditions of exposure, when the metal is sheltered from the rain and the corrosion products remain in contact with it, the humidity at which condensation takes place is probably determined by the deliquescence of the corrosion products. Condensation may, therefore, be expected to occur at different relative humidities for different metals. Experiments made with corrosion products scraped from corroded specimens showed that these products varied considerably in their capacity to absorb water. For example, the following increases in weight were observed when they were exposed for 48 hours to an atmosphere of 90 per cent. relative humidity:

Copper	8 per cent.
Aluminium	9 per cent.
Nickel	32 per cent.
Zinc	36 per cent.
Brass	68 per cent.

It might be concluded from these results that copper and aluminium were likely to be more resistant to corrosion under enclosed humid conditions than the other metals and this in fact proved to be the case. Unfortunately, iron was not included in this investigation and the properties of its corrosion product, rust, still need clarification. In laboratory tests ferric sulphate was found to be deliquescent, but ferrous sulphate and a sample of rust did not absorb appreciable amounts of moisture from atmospheres of 90 per cent. or more relative humidity.

2.3. Aqueous Corrosion.

It has been demonstrated beyond doubt that the great majority of corrosion processes are electrochemical in character. This certainly applies when the corrosive agent is water or an aqueous solution capable of conducting electricity. In such cases the corroding metal or metal system becomes divided into areas of two different types: the **anodes,** at which the metal corrodes, and the **cathodes,** at which it does not. These areas together with the solution in contact with them constitute an electric cell. This state of affairs exists, for example, when a piece of steel carrying broken millscale is immersed in sea-water (Fig. 3). A current flows between the bare steel and the millscale and as a result iron is dissolved at the bare areas, which act as anodes. The millscale-covered areas act as cathodes, where the initial products of the corrosion reaction are sodium hydroxide (caustic soda) and hydrogen. The same results would be obtained if an electric current

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were passed through the solution by connecting the bare areas to the positive pole of a battery and the millscale-covered areas to the negative pole.

A more elaborate discussion would be out of place in this article, but a few additional points may be made. First, it should be emphasised that this view of the mechanism of aqueous corrosion is no longer a vague theory but rests upon a solid foundation of experimental fact, in the building of which U. R. Evans and his co-workers at Cambridge have played an outstanding part. They have, for instance, detected and mapped the corrosion currents and demonstrated that they correspond in magnitude to the weight of metal corroded.

Secondly, any heterogeneity in the structure or surface of the metal itself, or in a combined metal system of which it may form a part, or in the external conditions to which it is exposed, will under appropriate conditions set up a corrosion cell. The effect of broken millscale on steel, mentioned above, is an example of the first factor; the accelerated corrosion of the steel parts of a ship's hull adjacent to fittings of non-ferrous metals is an example of the second, and the third is illustrated by the corrosion of steel dock gates exposed to waters of differing salinities, as when fresh river water flows out as a smooth layer over sea-water.

Thirdly, it will be noted that in the example given in Fig. 3, the cathodic products are sodium hydroxide and hydrogen. Unless the hydrogen is removed from the surface of the cathodes, it acts as a blanket, slowing down and ultimately stifling the cathodic reaction, thus stopping the corrosion process. In acid solutions, such as certain mine waters, the hydrogen is evolved as gas and corrosion can proceed apace; corrosion is then said to be of the "hydrogen evolution" type. More generally, however, particularly in solutions of neutral salts, such as sea-water, evolution of hydrogen cannot occur to an appreciable extent and the presence of oxygen is necessary to promote the cathodic reaction. In popular terms the function of the oxygen is to remove the hydrogen at the moment it is formed by oxidising it to water. This is the type of corrosion known as the "oxygen absorption" type and, where this mechanism comes into play, the rate of attack on the metal will often be controlled by the rate at which oxygen can reach the surface. In conformity with this, the rate of corrosion of steel immersed in sea-water has been found to decrease with the depth of immersion, as shown below.

Depth of Immersion Ft.	Loss in Weight Oz./Sq. Ft./Year
1	9.6
2.5	8.4
4	7.8

It is probable that this decrease continues with increasing depth and that little corrosion of the oxygen absorption type is possible at great depths, judging by the relative freedom from corrosion of ships salvaged after long immersion in deep water. Experimental evidence will be forthcoming on this point in several years' time, because the Post Office Research Station proposes to keep under observation a number of deep-sea telephone "repeaters" encased in steel that have recently been sunk on the bed of the Atlantic.

Lastly, it should be observed that in many cases of corrosion the final corrosion product may result from the reaction of the primary products produced at the anodes and cathodes and thus be formed at an appreciable distance from either areas. For example, reverting to Fig. 3, rust is produced at the places where the soluble iron chloride formed at the anodes meets the caustic soda formed at the cathodes, after these primary products have diffused away from the metal through the solution. The first result is the precipitation of ferrous hydroxide, $Fe(OH)_2$, which then changes gradually to the familiar yellow-brown rust by a sequence of reactions similar to those depicted in Fig. 1.

2.4. Microbiological Corrosion.

This short exposition of corrosion theory would be incomplete without some reference to microbiological corrosion. For a long time corrosion workers were puzzled by the fact that some of the worst cases of corrosion of buried iron pipes were found in waterlogged anaerobic soils, i.e. in soils which in their very nature contained no available oxygen for the corrosion process. This seemed to rule out corrosion of the oxygen absorption type and it was also clear that corrosion of the hydrogen evolution type did not occur. The explanation was provided by some Dutch investigators, notably H. Von Wolzogen Kühr. They proved that certain bacteria, which flourish in anaerobic soils can decompose sulphates when iron is present, converting them into suplhides. The oxygen originally present in the sulphates becomes available for removing the hydrogen formed at the cathodes of the corrosion cells in much the same way as atmospheric oxygen does so. The chemical reactions involved are not yet fully understood but for practical purposes may be represented as follows:

$$CaSO_4 \longrightarrow CaS + 4O$$

(One molecule of calcium sulphate, gypsum, a sulphate commonly present in soils, is capable of making 4 atoms of oxygen available for the corrosion process).

$$4Fe + 4O + 4H_2O \longrightarrow 4Fe(OH)_2$$

(In the presence of water these 4 atoms of oxygen corrode 4 atoms of iron, converting them into ferrous hydroxide).

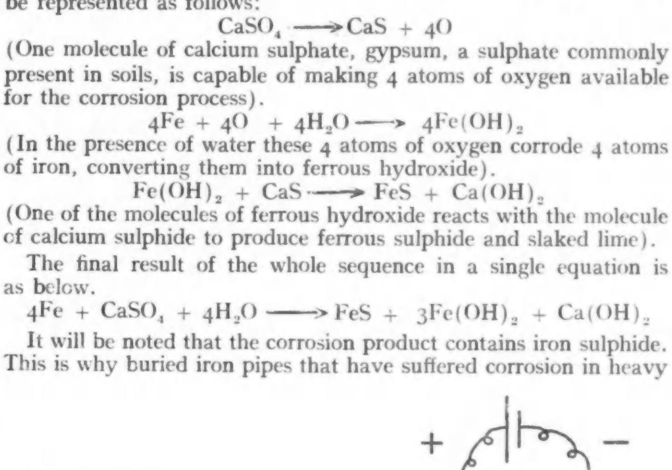
$$Fe(OH)_2 + CaS \longrightarrow FeS + Ca(OH)_2$$

(One of the molecules of ferrous hydroxide reacts with the molecule of calcium sulphide to produce ferrous sulphide and slaked lime).

The final result of the whole sequence in a single equation is as below.

$$4Fe + CaSO_4 + 4H_2O \longrightarrow FeS + 3Fe(OH)_2 + Ca(OH)_2$$

It will be noted that the corrosion product contains iron sulphide. This is why buried iron pipes that have suffered corrosion in heavy



Electrochemical corrosion of iron in the presence of millscale

Equivalent cell with external source of current (two iron electrodes).

Fig. 3. Electrochemical Corrosion. Iron with Millscale.

clay soils through the intervention of sulphate-reducing bacteria are usually found to be surrounded by a thick black crust of earth and corrosion product, which gives off the characteristic smell of sulphuretted hydrogen when it is wetted with hydrochloric acid.

In recent years extensive research on microbiological corrosion has been conducted at the Chemical Research Laboratory, Teddington, notably by H. J. Bunker and K. R. Butlin. In a report with W. H. J. Vernon[1], the latter states that in investigations of service failures made in collaboration with the Institution of Water Engineers, no fewer than 44 out of 53 cases of serious external corrosion of buried water pipes water found to be due to the action of sulphate-reducing bacteria. Of the remainder, six came from soils containing ashes and clinker and three from mixtures of clay and clinker.

Sulphate-reducing bacteria are also found in the sea and in natural waters. For instance, they can flourish in the silt and mud of a sea or river bed. Some cases of marine corrosion are undoubtedly attributable to them. W. S. Patterson has recently described a case in which a new ship was moored in a river estuary during fitting-out in such a way that for appreciable periods between tides her bottom rested on mud banks[2]. These mud banks consist of deposited clay and silt, polluted with organic matter from sewage discharged into the river, so that they constitute an ideal breeding ground for anaerobic bacteria. When the ship was drydocked 5 months after launching, her bottom plates and rivets were found to have suffered severe corrosion of the pitting type. Patterson concluded that sulphate-reducing bacteria were mainly responsible for the attack on the steel. He demonstrated this by

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conducting tests on pieces of mild steel plunged in samples of mud taken from the banks and held at 37° C. for 42 days. Half the tests were made in the fresh mud and the others in the same mud after it had been sterilised. The average losses in weight through rusting of three specimens under each set of conditions were:

In unsterilised mud ... ... 1.56 g. per dm²
In sterilised mud ... ... 0.07 g. per dm²

It should be emphasised, however, that, although sulphate-reducing bacteria permit the corrosion of steel to take place under conditions in which it would not otherwise occur, the rate of corrosion is not necessarily any greater than would result from straightforward corrosion of the oxygen-absorption type. Thus in the laboratory experiment quoted above the loss in weight of the steel plates in the unsterilised mud is equivalent to corrosion at the rate of about 6.8 mils per year[3]. As will be shown later in section 3.2, the normal rate of corrosion of steel immersed in sea-water is roughly 4 mils per year. The difference between this figure and that of 6.8 mils per year observed in the laboratory test is no greater than would be accounted for by the fact that the latter test was made at a temperature of 37° C. (roughly 100°F.).

3. The Corrosion of Bare Steel

This section of the article will be devoted to a short exposition of what is known regarding the resistance of ferrous metals to corrosion when exposed without protection to the three main natural corrosive media: the atmosphere, salt and fresh waters, and the soil. Representative figures will be given for the rates of corrosion in these media and the effects of differences in the composition of the iron or steel on these rates will be discussed. All these facts are now reasonably well established as a result of researches by individuals and more extensive collaborative investigations conducted by, *inter alia*, the Institution of Civil Engineers, the Iron and Steel Institute and the British Iron and Steel Research Association, in this country, the U.S. National Bureau of Standards and the American Society for Testing Materials, in the United States, and l'Office Technique pour l'Utilisation de l'Acier, in France

3.1. Atmospheric Corrosion.

The available data will be discussed under three heads: (i) effect of the climate; (ii) effect of the duration of exposure; (iii) effect of the composition of the iron or steel.

(i) **Effect of Climate.** The effect of climatic differences on the corrosion rate of bare unalloyed structural irons and steels is well represented by the figures below. These are the observed average corrosion rates for small plates of ingot iron (a steel with a very low carbon content) exposed at the places mentioned for several periods of one year each.

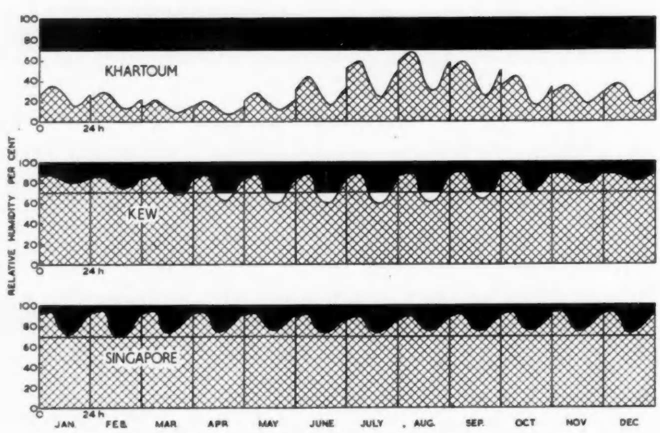

Fig. 4. Variation in Atmospheric Humidity at Khartoum, Kew and Singapore. The average humidity for the 24 hours of the day is plotted for each month of the year. The black band between 70 and 100 per cent. relative humidity represents the conditions under which marked rusting can occur.

Type of Atmosphere	Locality	Rate for Rusting Mils (0.001 in.) per Year
Great Britain		
Rural	Llanwrtyd Wells ...	2.5
Marine	Brixham	2.1
	Calshot	3.1
Urban	Birmingham	4.1
Industrial	Sheffield	5.4
	Derby	6.8
Overseas		
Dry tropical	Khartoum	0.1
Sub-polar	Abisko, N. Sweden ...	0.2
Dry sub-tropical	Basrah	0.6
Marine tropical	Singapore	0.6
Temperate industrial	Congella, near Durban	4.5
Surf-beach tropical	Lighthouse Beach, Lagos	24.4

[1] K. R. Butlin and W. H. J. Vernon. "Underground Corrosion of Metals: Causes and Prevention." Journal of the Institution of Water Engineers, 1949, pp. 627-637.
[2] W. S. Patterson. "External Ship Corrosion Due to Bacterial Action." Transactions of the North East Coast Institution of Engineers and Shipbuilders, 1951, 68, pp. 93-106.
[3] A mil is 0.001-in.

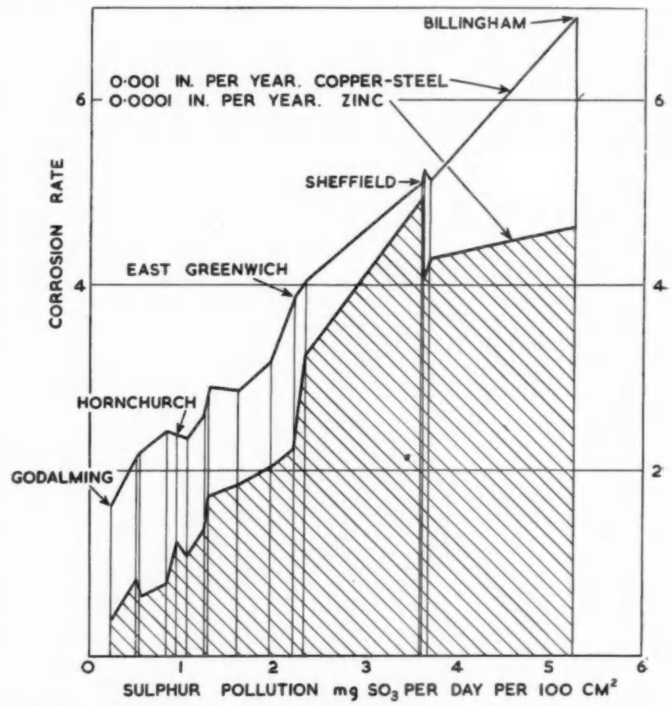

Fig. 5. Correlation between Atmospheric Corrosion and Sulphur Pollution of the Air. Values are given for the corrosion rates of copper-steel and zinc at 16 sites in Great Britain where the sulphur pollution of the air is recorded by absorbing it on a gauze of known area smeared with lead peroxide paste. A few typical sites are named in the diagram. Note that the vertical scale is ten times greater for copper-steel than for zinc.

The practical significance of these results may be illustrated by considering what might be expected to happen to an ordinary wire link fence of 17 G (0.056-in.) galvanised steel wire, like those used by the Forestry Commissioners. In the Hope Valley district near Sheffield, because of the smoky atmosphere, such a fence will only last for about 3 years, unless steps are taken to protect it by painting with tar. Its life at Brixham might be estimated as about 8 years. At Khartoum it should still be serviceable after 100 years but on Lighthouse Beach, Lagos, it would disintegrate within a year. Something like 25 years' service should be obtained at Singapore.

It will be appreciated that these figures are given merely by way of illustration and that major differences in the corrosiveness of the atmosphere may occur within narrow limits in any given locality, because of extraneous conditions. The results do, however, bring

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out clearly two facts: first, that there are enormous differences in the corrosion rates of steel in different parts of the earth and, secondly, that on the whole corrosion overseas is less severe than in this country.

These facts are a logical outcome of the principles already discussed in section 2.2. when considering Fig. 2. The low corrosion rate at some of the overseas stations is primarily due to the relative dryness of their atmosphere. For example, at Khartoum the average value of the maximum relative humidity at any time of the year, recorded over a number of years, is 67 per cent. The differences in the local atmospheric humidity at home and overseas are illustrated in Fig. 4, which shows the variation in relative humidity throughout the year at Kew, Khartoum and Singapore. It is clear from these curves that in Great Britain, as typified by Kew, the relative humidity lies above the lower limit of the critical value, 70 per cent. for something like 80 per cent. of the year; during this period corrosion can proceed if the other conditions are favourable. On the other hand, at Khartoum this limit is never reached. At Singapore, the lower limit is exceeded for 90 per cent. of the time and at other places in the tropics, for which figures are not given, the relative humidity seldom falls below this value. Yet often serous corrosion does not occur at these places because of the absence of the second factor needed for severe rusting—appreciable atmosphere pollution.

When the humidity conditions favour corrosion, the rate at which rusting occurs is controlled by the degree of pollution of the atmosphere. This was clearly demonstrated by the results of some experiments in which the British Iron and Steel Research Association and the Fuel Research Station collaborated. In brief, small plates of copper-steel and of zinc were exposed outdoors at 16 sites in Great Britain where measurements of the atmospheric pollution are made as a matter of routine. These sites were selected in groups of four, representing slight, moderate, heavy and severe sulphur pollution, and at each the specimens were exposed immediately beside the pollution gauge. It is evident from the results which are shown in Fig. 5, that there is a very close correlation between the corrosion of both metals and the degree of sulphur pollution.

It is the lack of sulphur pollution that accounts for the low rates of corrosion observed at places in the tropics, like Singapore, where the relative humidity of the atmosphere is high and conducive to rusting. However, on tropical shores rusting can occur at a devastating speed, as is shown by the figure of 24.4 mils per year given above for ingot iron exposed on Lighthouse Beach, Lagos. This extreme rate of rusting is due to the fact that the steel is continually enveloped in a mist of salt spray from the sea. The amount of salt in the air decreases rapidly on moving inland and there is a corresponding diminution in the degree of corrosion. This is shown by the following figures obtained by the Tropical Testing Establishment, Ministry of Supply, for specimens exposed on Lighthouse Beach.

Distance from the Surf Yd.	Salt Content of the Air*	Corrosion Rate Mils per Year Ingot Iron	Zinc
50	11.1	37.7	1.51
200	3.1	14.9	0.57
400	0.8	2.2	0.11

*mg. of sodium chloride per 100 sq. cm. per day.

The specimens were exposed for a complete year and the salt content of the air was determined by hanging a wet cloth across the wind for a few hours and measuring the salt collected.

The Delhi Pillar. As a final example of the effect of meteorological conditions on corrosion, reference may be made to the results of some tests carried out in the neighbourhood of the famous iron pillar at Delhi. This ancient monument, which is fifteen centuries old, has long been an object of curiosity because of its notable freedom from appreciable rusting. Recently the British Iron and Steel Research Association arranged for some small plates of copper-steel and of zinc to be exposed near the pillar for one year. When the specimens were returned to England, they were found to have corroded very little; the zinc which had been cold-rolled, still retained much of its original natural polish. The rates of corrosion, deduced from the losses in weight after removing the corrosion products, were 0.20 mils per year for copper-steel and 0.006 mils per year for zinc. The latter is equivalent to a loss of about 0.0036 oz. of zinc per sq. ft. per year; at this rate the coating on an ordinary galvanised sheet would last for something like 150 years.

The explanation of these low corrosion rates is provided by the meteorological date for Delhi, which are as follows:

	Relative Humidity Per Cent 0830h	1730h	Rainfall In. Total
January	74	46	0.9
February	52	24	0.0
March	53	33	2.1
April	42	21	0.9
May	35	21	0.1
June	41	26	0.5
July	63	48	4.8
August	75	60	3.1
September	63	52	4.1
October	50	37	0.3
November	50	42	0.6
December	69	47	Nil
Total for the year			17.4

These observations were taken during 1951, one of the years in which the corrosion tests were made, and may differ slightly from

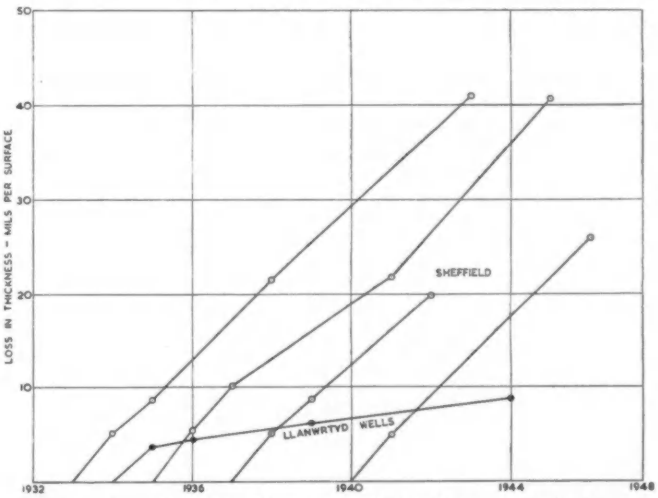

Fig. 6. Corrosion/Time Curves for Mild Steel at Sheffield and Llanwrtyd Wells. The results relate to ⅜-in. thick plates of ordinary mild steel exposed vertically in the open air.

the average values for a period of years. It will be seen that none if the 24 observations for the relative humidity exceeds 80 per cent. and that only two observations are greater than 70 per cent. Moreover, the total rainfall, 17.4-in., is little more than half the average rainfall for the driest places in the British Isles. It seems, therefore, that the longevity of the Delhi Pillar is to be attributed to the fact that the local climatic conditions are not conducive to corrosion rather than to any outstanding properties of the iron from which it is made.

(ii) **Effect of duration of exposure.** The rate of rusting of steel in the open atmosphere is not constant throughout the year and, if a series of bright steel specimens were exposed at intervals for the same short period, they would probably differ widely in the degree to which they corroded. For example, G. Schikorr has observed that the rate of rusting in mils per year for specimens exposed in Berlin for consecutive periods of one calendar month varied from a minimum of 1.8 in June to a maximum of 5.0 in November and in December. Incidentally, Schikorr showed that these variations were closely associated with the corresponding monthly variations in atmospheric pollution. There is also evidence, into which we need not go in detail, that the influence of the conditions prevailing during the early stages of exposure may persist for an appreciable time after these conditions have ceased to exist; e.g. a specimen first exposed to corrosion when the conditions are but mildly aggressive may continue to corrode at a low rate when it passes into a more aggressive period, and *vice-versa*. However this may be, for practical purposes we are mainly concerned

[4]The steel used was a copper-steel containing 0.28 per cent. of copper and would suffer less corrosion than ordinary steels with lower copper contents. (See Fig. 7.)

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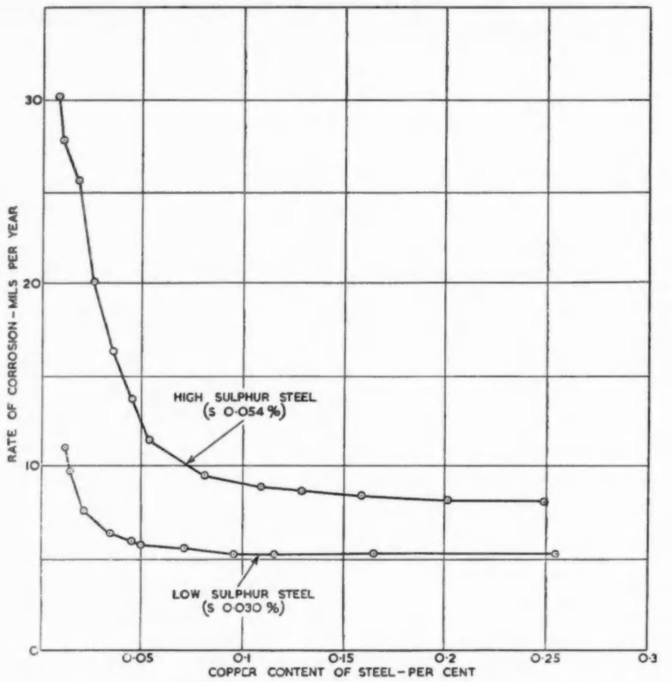


Fig. 7. Effect of Copper Content on the Resistance of Steel to Atmospheric Corrosion (D. M. Buck).

with the corrosion that takes place over a number of years. Then the position is much simpler, for the short-period fluctuations in the meteorological conditions tend to average themselves out. The shape of the corrosion/time curve for ordinary structural steels exposed in the open air for a number of years has been observed by several investigators in different countries and is now well established. The curves shown in Fig. 6, which are based on the results of tests by the British Iron and Steel Research Association at Sheffield (an industrial atmosphere) and Llanwrtyd Wells (a rural atmosphere) may be regarded as representative.

It is evident from these curves that the relationship between the corrosion of mild steel and duration of exposure was to all intents and purposes a linear one from about the end of the first year's exposure onwards. This exception during the early stages is mainly explained by the fact that the specimens were exposed in the as-rolled condition, i.e. with the millscale on them. Consequently, the loss in weight recorded over the first year or so was augmented by the weight of the millscale, which was shed during that period. It is probable, too, that the progressive formation of a continuous layer of rust on the steel surface plays a part in reducing the corrosion rate. After the initial stage the slopes of the straight lines shown in Fig. 6 are remarkably uniform, both in the industrial atmosphere of Sheffield and the rural one of Llanwrtyd Wells. These slopes correspond to rates of rusting of 4.0 mils per year at Sheffield and 0.60 mils per year at Llanwrtyd Wells.

It may be concluded, therefore, that for practical purposes the degree of rusting caused by atmospheric exposure may be taken to be proportional to the duration of exposure, so that figures observed for the rates of rusting over a few years at different localities may be used to predict with reasonable accuracy the lives of bare steel sections exposed to the atmospheres concerned.

(iii) **Effect of differences in the composition of the iron or steel.** It is fortunate that the resistance of iron or steel to atmospheric corrosion can be greatly increased by the addition of alloying metals. Steels with increased resistance to corrosion fall into two groups: the rust-resisting steels proper, which are virtually immune to attack, and the low-alloy steels, which undergo rusting but are several times, say up to six times, more resistant than ordinary unalloyed steel. Before passing on to consider the corrosion-resisting properties of these groups of steels, it may be of interest to make a few remarks about the relative merits of the different varieties of the available unalloyed irons and steels.

Comparison of ordinary structural irons and steels. Experiments have shown that the relative merits of wrought iron and mild steel depend upon the quality of the wrought iron used for the comparison. British wrought irons, which contain about 1 per cent. of slag (mainly oxides of silicon and phosphorus) are more resistant to atmospheric corrosion than ordinary mild steel say by one-third. On the other hand, the much purer Swedish irons, with less than 0.2 per cent. of slag, are more corrodible than ordinary mild steel by approximately the same amount. This is a good illustration of the fact that purity in a metal does not necessarily decrease its tendency to corrode.

The reasons for the better corrosion resistance of the ordinary wrought irons have not yet been fully explained. This is generally believed to be associated with their phosphorus content, which is higher than that of steel, and with their peculiar laminated structure, which results from the processes introduced into their manufacture, in which crude bars are cut up, piled in pieces on top of each other and then re-rolled.

Variations within accepted commercial limits of the carbon, manganese, silicon, phosphorus and sulphur contents of unalloyed steel do not produce any marked changes in its corrosion resistance. A high sulphur content may increase corrosion under certain conditions; for example, it is undesirable to use high sulphur steels for the manufacture of tinplate subsequently used in the canning industry. (See also Fig. 7 later). "Killed" steels containing 0.2 per cent. or so of silicon are less corrodible than the "balanced" steels with a lower silicon content commonly used for the production of plates and sections for structural purposes, but the difference is only of the order of 10 per cent. and has no practical significance. In general, therefore, there is no evidence that common structural steels produced by the normal processes, i.e. acid or basic open-hearth, acid or basic Bessemer, differ appreciably in their resistance to atmospheric corrosion. This remark applies to steels in the bare condition and it is certain that any slight differences that there may be between them dwindle into insignificance when they are painted or protected from corrosion by a metallic coating or other means.

Low-alloy steels. Of far greater importance are the effects of small quantities of alloying elements deliberately added to the steel. One of the first to be added in this way was copper. Steel containing about 0.2 per cent. or more of this metal is roughly half as resistant again to atmospheric corrosion as unalloyed steel. The pioneer in the development of the "copper-steels" was the American metallurgist, D. M. Buck. Some early results obtained by him are shown in Fig. 7; they related to steel sheets exposed in the open air in an industrial atmosphere. It will be seen that the addition of even a small percentage of copper reduces the corrosion of steel considerably. The reduction is progressive with increasing additions of copper until about 0.15 per cent. of copper is reached. Beyond this the effect of further additions is less pronounced and there is no substantial difference in the resistance to corrosion of steels containing, say, 0.2 and 0.5 per cent. of copper.

Buck's conclusions have been fully confirmed by subsequent investigators, notably by the American Society for Testing Materials, who, from 1916 onwards, undertook an extensive series of field trials of steel sheets of different characteristics and copper contents. Some of these tests are still in progress at Annapolis, where, at the last recorded inspection, a solitary survivor of 22 G (0.030-in.) sheets remained unperforated after 33 years' exposure. It is of Bessemer steel containing 0.53 per cent. of copper.

These researches paved the way for intensive investigations of a whole range of alloy additions. As a result, several so-called "low-alloy steels" have been put on the market. These are low or medium carbon steels, chiefly used for structural purposes; as a rule, they combine increased tensile strength with greater resistance to atmospheric corrosion. In this article we are solely concerned with the latter property, which may be illustrated by the figures given below.

Steel	Alloying Elements	Rate of Rusting Mils per Year	Sulphur Content of Rust As SO_3 per Cent
X2	None	4.3	2.31
YF	Cu 0.4%	3.2	2.51
KW	Cr 0.5%; Cu 0.2%; Si 0.8%	1.9	2.68
EW	Ni 3.1%	1.1	3.27

Corrosion of Iron aud Steel—continued

These are representative results for a group of sixteen commercial low-alloy steels of British and American origin that were exposed in an industrial atmosphere at Sheffield for six years. The figures indicate the overall range of improvement that can be effected by the addition of small percentages of alloying elements. Steel EW, containing three per cent. of nickel is about four times more resistant to corrosion than the ordinary unalloyed structural mild steel X2. It is fair to say that under certain conditions of outdoor exposure some of the commercial low-alloy steels now on the market might prove up to six times better than ordinary steel.

Rust-resisting steels. The rust-resisting steels proper, which are characterised by a high chromium content, generally combined with an appreciable percentage of nickel, rank among the aristocrats of the anti-corrosion world. Under straightforward conditions of atmospheric corrosion, the best of them are virtually incorrodible, as is shown by the following table in which they are compared with some common non-ferrous metals and with an ordinary and two low-alloy steels. The data relate to complete exposure outdoors in an industrial atmosphere.

Metal	Rate of Rusting Mils per Year	Estimated Life of an 18G (0.048 in.) Sheet. Years
Rust-resisting steels[5]		
18/8/2½ chromium-nickel-molybdenum steel ...	0.001	48,000
18/8 chromium-nickel steel	0.1	480
Non-ferrous metals		
Lead	0.3	160
Copper	0.3	160
Aluminium	0.6	80
Zinc	0.6	80
Structural steels		
1.0/0.5/0.5/0.15 chromium-copper - silicon - phosphorus steel	1	48
0.3 per cent. copper-steel	4	12
Ordinary mild steel ...	5	10

It will readily be understood that these figures are given as illustrations only. For example, in an actual test the four non-ferrous metals would not necessarily always finish up in the same order of merit; much would depend upon the local conditions. Moreover, the hypothetical figures for the life to perforation of a sheet of the metal 18 G (0.048-in.) thick, exposed to corrosion on one side only, might in practice be curtailed by pitting or, on the other hand, prolonged by the formation of a protective film over a period of years, as might well happen for lead exposed in a sulphurous atmosphere. They do, however, serve to bring out the magnitude of the differences in the corrosion resistance of the various metals.

Reasons for the corrosion resistance of low-alloy and rust-resisting steels. The reader will naturally ask what are the reasons for the superior rust-resistance of the low-alloy steels and of the rust-resisting steels and it may be of interest to pause for a moment to answer this question. The explanation differs for the two types of steels.

The rust-resisting steels proper owe their immunity from corrosion to the innate rapidity at which they corrode! Their surface is normally covered with a tough and resistant film of oxide. If this is removed by damage, the metal below corrodes so rapidly that the film heals immediately and further attack ceases. The existence of this film is no myth but a well established fact. If rust-resisting steel is immersed in a solution of iodine in anhydrous methyl alcohol, the metal is dissolved and the oxide film remains behind. This method was used by W. H. J. Vernon, F. Wormwell and T. J. Nurse to isolate the film and they described its properties in a paper published in 1944. They found that it consisted of oxides of iron, chromium and nickel. In general, the percentage of chromium oxide present in the film increased as the surface of the steel was made smoother before being exposed to oxidation. The films on the most highly polished specimens contained 90 per cent. of chromium oxide. This observation agrees with the fact that the corrosion resistance of rust-resisting steels is improved by polishing. The thickness of the film was of the order of one quarter of one millionth of an inch, or, to express the result in another way, a pile of 5,000 pieces of the film would be equal in thickness to a piece of cigarette paper.

Low-alloy steels also depend for their increased resistance to corrosion on the formation of a protective surface layer. Whereas, however, on the rust-resisting steels, the layer is a thin film of oxide, on the low-alloy steels it consists of rust. It was noticed, even in the early days of the use of copper-steels, that the rust formed on them was more compact and darker in colour than the rust on ordinary steel. The same holds true generally for the low-alloy steels that have followed copper-steel: they corrode more slowly than ordinary steel, because they give rise to a rust that is less permeable to air and moisture than that on ordinary steel.

This physical difference in the rusts on ordinary and low-alloy steels is associated in some way with differences in their chemical constitutions. Independent researches by H. R. Copson in the United States and by the British Iron and Steel Research Association agree in showing that the rusts on low-alloy steels have a higher sulphate content than those on unalloyed steels and that an enrichment in the alloying elements takes place in the former, e.g. the ratio of copper to iron in the rust on a copper-steel is greater than the corresponding ratio in the steel itself. Copson believes, and there seems to be some foundation for his view, that insoluble basic sulphates of the alloying elements, copper, nickel, etc., accumulate in the rust on the low-alloy steels and contribute to its relative impermeability. Be this as it may, there is certainly a direct correlation between rust-resistance and the sulphate content of the rust. This is shown by the results depicted in Fig. 8 for the 16 low-alloy steels tested at Sheffield to which reference was made above.

It should be stressed that, as low-alloy steels depend for their superior resistance to corrosion on the protective properties of their rust, they obviously lose their advantage under conditions where either rusting does not take place—when, of course, rust-resistance is immaterial—or where rust forms in such a way that it does not adhere to the steel. Consequently, low-alloy steels are at their best when exposed to outdoor atmospheres and do not show to such marked advantage when subjected to other conditions, e.g. when immersed in the sea or when buried in the soil. Nor, in general, is there much difference in corrosion resistance between low-alloy steels and ordinary steel when exposed to the air under sheltered conditions, e.g. tests by the British Iron and Steel Research Association showed that railway sleepers of ordinary and copper-steel rusted at the same rate in the Severn Tunnel, although in the open track the copper-steel sleepers were appreciably less attacked.

(To be continued)

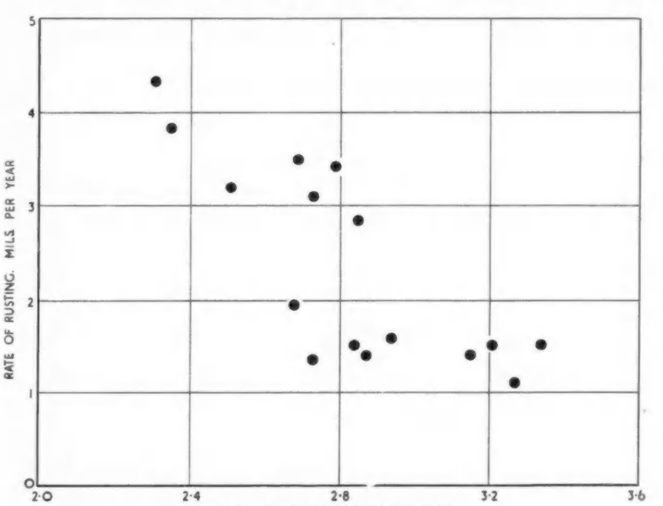


Fig. 8. Correlation between Resistance to Atmospheric Corrosion and Sulphate Content of Rust. The results relate to 16 ordinary and low-alloy steels that were exposed outdoors at Sheffield for six years.

[5]The figures for rust-resisting steels are based on experimental results given by H. T. Shirley and J. E. Truman in their paper, "A study of the Corrosion Resistance of High-Alloy Steels to an Industrial Atmosphere," Journal of the Iron and Steel Institute, 1948, Dec., 367-375.

Tonnages of Ships

Relation to Freight Earning Cargo Space

By R. J. W. RUDKIN, B.Sc.
(Vickers-Armstrongs Ltd., Naval Yard)

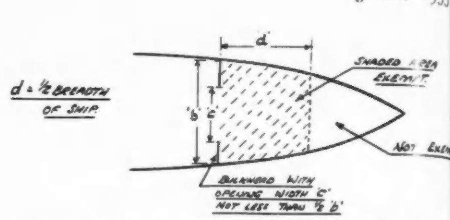


Fig. 2 Exemption under Suez Canal regulation

When the word " tonnage " is used it invariably refers to the measured tonnage, or more correctly, the Gross Registered Tonnage (G.R.T.) or the Net Registered Tonnage (N.R.T.). The unit, one ton, referred to in these cases is a measured volume of 100 cubic feet. The Net Registered Tonnage is used as the basis for charging harbour, light, towage, canal and other dues.

Oher terms are displacement and deadweight—these are both measured in tons of 2,240 lbs.

There is one other figure which is used exclusively for sailing yachts and that is " Thames Measurement " which is given by the formula:—

$$\text{T.M.} = \frac{(L—B) \times B \times B/2 \text{ in tons}}{94}$$

Where L = Length on deck from fore side of stern to after side of stern port.
B = Extreme beam.

Historical Outline

Originally, the word " ton " did not indicate a measure of weight but has been derived from the old English word " tun." This word probably dates back to the early Middle Ages where the word " tunna " is found in monastic Latin, meaning a barrel, but it does not occur in classical Latin unless it is a corruption of " tina " which means a wine ship.

In early days, the tonnage of ships was connected with the number of " tuns " of wine they could carry. The capacity of a wine barrel became definite in about 1423 when an enactment was passed under Henry V defining a " tun " as 252 gallons of wine at $6\frac{1}{4}$ gallons to the cubic foot. This would give the tun an internal capacity of $40\frac{1}{3}$ cubic feet and, allowing for the thickness of the cask, a tun would measure externally about 42 cubic feet. This figure or one close to it has been used in tonnage measurement for centuries. Even now among shipping men a " freight ton " of 40 cubic feet is still in use. The weight of a tun of wine was also used as a unit and the " tun-weight " came to be accepted as 2,240 lbs.

Various formulæ for tonnage have been used since the seventeenth century, including Builders Old Measurement in 1773.

$$\text{B.O.M.} = \frac{(L—3/5B) \times B \times B/2}{94}$$

Where L = Length of ship measured on keel.
B = Breadth to outside of planking amidships.

This rule did not include the depth of the ship as a factor, which led to ships being built of great depth in proportion to their breadth; such ships were often unstable in many conditions of loading and unseaworthy. Eventually depth was again included in tonnage formulæ

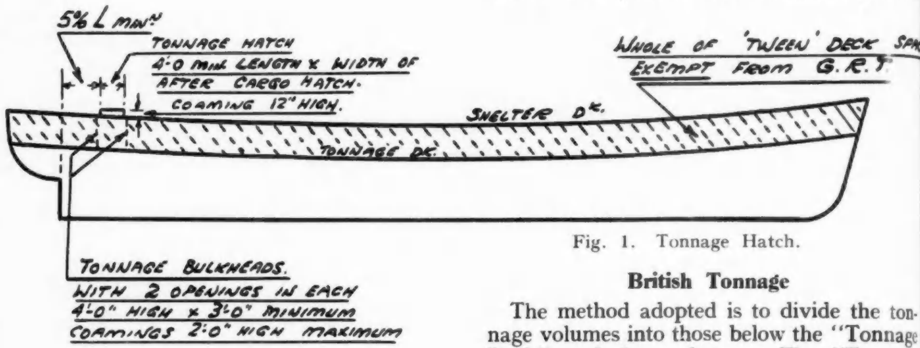


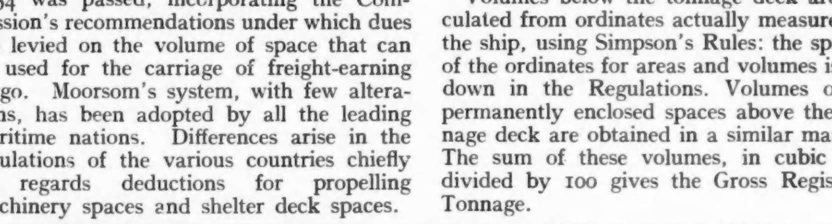
Fig. 1. Tonnage Hatch.

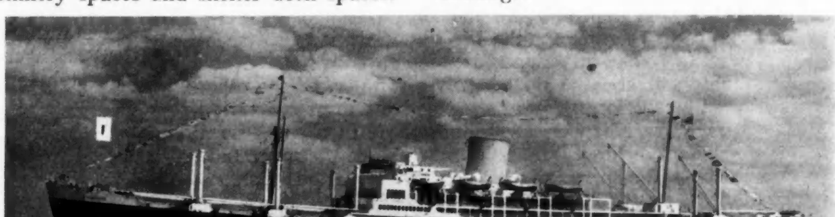
In 1849 a Commission was appointed, with Mr. George Moorsom as Secretary, to report on tonnage measurement. As a result of this Commission the Merchant Shipping Act of 1854 was passed, incorporating the Commission's recommendations under which dues are levied on the volume of space that can be used for the carriage of freight-earning cargo. Moorsom's system, with few alterations, has been adopted by all the leading maritime nations. Differences arise in the regulations of the various countries chiefly as regards deductions for propelling machinery spaces and shelter deck spaces.

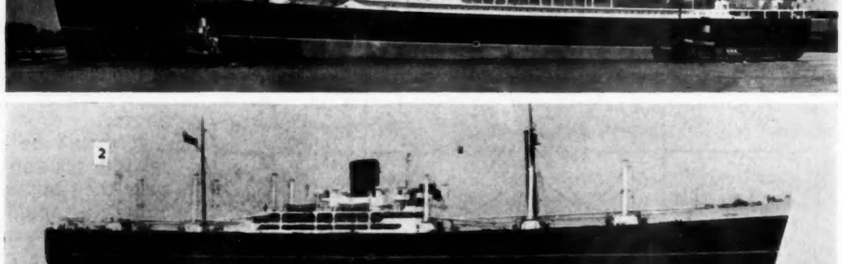
British Tonnage

The method adopted is to divide the tonnage volumes into those below the "Tonnage Deck" and those above. The "Tonnage Deck" is defined as the uppermost deck in vessels of one or two decks and the second continuous deck from below in vessels of three or more decks.

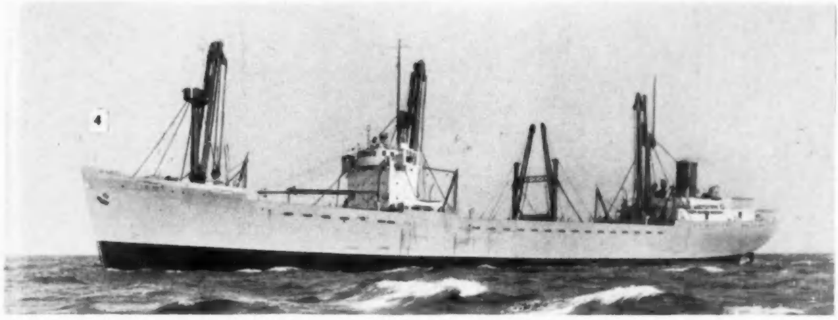
Volumes below the tonnage deck are calculated from ordinates actually measured on the ship, using Simpson's Rules: the spacing of the ordinates for areas and volumes is laid down in the Regulations. Volumes of all permanently enclosed spaces above the tonnage deck are obtained in a similar manner. The sum of these volumes, in cubic feet, divided by 100 gives the Gross Registered Tonnage.







Tonnages of Ships—continued



Double bottom tanks are not included in the G.R.T. unless used for fuel, stores or cargo oil.

Spaces above the tonnage deck fall into three categories:—

1. The following enclosed spaces are included in the G.R.T.:—
   (a) Spaces enclosed without openings in sides, ends or deck sufficiently large to qualify the spaces as "open."
   (b) Spaces with openings in sides or ends, which are fitted for passengers or crew.
2. The following are occasionally included:—
   (a) Volume of hatchways when more than ½ per cent. of the G.R.T.
   (b) Parts of the machinery casings at Owner's option, when used for propelling machinery space deduction.
3. Spaces exempt from the G.R.T.
   (a) Crews' galley and bakery, crews' lavatories, companionways, deck-houses containing machinery and so on.
   (b) Deck spaces which have openings, in sides, ends or deck, above a specified size without permanently fixed means of closing them (see below "Shelter Deck Ships").

The Net Registered Tonnage is obtained by making certain deductions from the Gross Registered Tonnage. Only spaces which have been included in the G.R.T. on the first instance may be deducted to obtain the N.R.T.

Deductions for N.R.T.

(a) Spaces for propelling machinery up to the crown of the machinery space including shaft tunnels and stokeholds but excluding bunkers in way of the machinery space. If desired, light and air casings above the crown of the machinery space may be added to the Gross to make up the required tonnage of the machinery space. The volume of the machinery space must be reasonable and only large enough for safe working. When the total volume has been obtained, it is expressed as a percentage of the G.R.T. If its value is between 13 per cent. and 20 per cent of the G.R.T. for screw driven vessels, a deduction of 32 per cent. is allowed. (In paddle steamers, if between 20 per cent. and 30 per cent. then 37 per cent. deduction is allowed). Outside these limits $1\frac{3}{4}$ times the actual volume is deducted for screw driven vessels ($1\frac{1}{2}$ times actual volume for paddle steamers). Limits are imposed for the propelling machinery space deduction, otherwise high-powered vessels, such as tugs, could have a zero or even negative Net Tonnage. These limits are that the maximum deduction for the propelling machinery space is fixed as:—maximum deduction allowed = 55 per cent. of (G.R.T.—tonnage of crew spaces). This rule encourages generous proportions for the crew accommodation if the minimum value of the N.R.T. is to be obtained.

(b) All crew spaces are deducted including Captain's quarters (within reason), crews' hospitals, wireless room and similar spaces.

(c) Auxiliary machinery spaces below tonnage deck such as anchor gear, capstan machinery, steering gear, pump rooms and cofferdams in oil tankers are deducted.

(d) Navigational spaces including boatswain's stores (maximum 1 per cent. G.R.T.), Chart Room, when used exclusively for navigation instruments (up to 75 tons), sail room (up to 2½ per cent. G.R.T.), are deducted from the G.R.T.

A large proportion of the world's merchant tonnage has a N.R.T. in the neighbourhood of 60-65 per cent. of its G.R.T.

Shelter Deck Ships

Resulting from the regulations which apply to cargo spaces above the tonnage deck, but which have openings in either deck, ends or sides, the type of ship known as a "Shelter Deck Ship" has been developed. This is the greatest anomaly resulting from the present Tonnage Regulations.

For the whole of the shelter 'tween decks to be exempt from tonnage measurement (i.e.: not included in the G.R.T.) a tonnage hatch and tonnage well has to be fitted. The position and size of the hatch and the openings in the tonnage bulkheads are indicated in Fig. 1. The wood hatch covers

Name of Ship	Photo	Type of Ship	COMPARATIVE TONNAGES					Light Ship Tons*	Dead-Weight Tons*	Load Displacement Tons*
			Length B.P.	Breadth	Depth	G.R.T.	N.R.T.			
Rangitoto	1	Passenger-Cargo Liner	575′–0″	78′–0″	43′–0″	21,808	12,412	13,700	15,000	28,700
Ocean Monarch	–	Luxury Passenger Liner	475′–0″	72′–0″	39′–0″	13,654	7,135	8,800	4,300	13,100
Hurunui	2	Shelter-Deck Cargo Liner	530′–0″	70′–0″	47′–3″	11,275	6,640	9,382	14,940	24,322
Pacific Reliance	–	Cargo Liner, 12 Passengers	470′–0″	63′–2″	41′–0″	9,441	5,561	6,000	10,500	16,500
Atreus	–	Cargo Liner, 12 Passengers	452′–9″	62′–0″	35′–3″	7,799	4,544	5,927	9,280	15,207
City of New York	3	Cargo Liner, 12 Passengers	465′–0″	64′–0″	36′–3″	8,419	4,201	6,022	10,710	16,732
Beljeanne	4	Special Cargo Ship 120 ton Derricks	445′–0″	66′–6″	33′–6″	7,843	4,471	4,691	10,330	15,021
Credo	5	Oil Tanker	565′–0″	80′–0″	42′–6″	16,354	9,453	7,530	25,150	32,680

* 1 Ton = 2,240 lbs.

Tonnages of Ships—continued

may only be secured by hemp lashings from below and only one canvas cover may be fitted. The openings in the bulkheads must only be secured by shifting boards or by plates fastened with hook bolts, no holes being pierced in the bulkheads for fastenings. Scuppers, fitted with non-return valves, drain the tonnage well.

In theory the whole of the 'tween decks, under the above conditions is considered unsuitable for cargo, but in practice it is as good a cargo space as anywhere else in the ship. The shelter deck, with tonnage hatch, is supposed not to prevent the ingress of water for tonnage purposes, but for the Load Line Regulations a considerable proportion of the 'tween decks is allowed to be counted for reserve of buoyancy (for which purpose it must be reasonably watertight).

The displacement of a ship at a given draft is the actual weight of the ship and all its contents at that draft, measured in tons of 2,240 lbs. The load displacement may be split up as follows :

Hull and outfit, Machinery — These items are known as " light ship " or " light weight."

Provisions, Stores, Fresh water, Crew and effects, Reserve feed water, Fuel, Cargo and/or passengers — Deadweight.

Of the deadweight items, only the cargo and/or passengers are freight-earning items.

Conclusions

Figures quoted in Lloyds Register and other returns of Merchant Shipping are in Gross Registered Tons. When comparisons are made of merchant ships, it is usually on a basis of G.R.T.

Oil tankers are usually quoted on a basis of deadweight in tons of 2,240 lbs. The figures often refer to the actual weight of cargo oil and oil fuel which can be carried.

Echo Sounding of Jetties

Use of Sounding Substense Board

By Lieut.-Comdr. A. D. MARGRETT, R.D., R.N.R.

The Echo Sounder is invaluable for rapid surveying of navigational areas such as channels, rivers and harbour approaches when the finished results are plotted to a scale of 1/2500 or similar. However, difficulty is encountered when sounding jetties to large scales such as 20-ft. to an inch. In this case, due to problems in fixing, the Echo Sounder is often rejected and a sounding pole or hand lead used instead. Thus the normal method is to row out from a jetty in a small boat or punt and at the same time pay out a calibrated taut line. Spot soundings are then taken every 10-ft. off the jetty. Attempts have also been made with the Echo Sounder in running lines parallel to the jetty at various distances off. This is not very successful, quite apart from the difficulty in fixing, due to the fact that the oscillator is travelling parallel to the contours and not at right angles to them. Consequently an error of even a few feet in fixing the distance off will seriously upset the contours of the plotted soundings.

In using the Echo Sounder for this type of sounding transit lines must be run at right angles to the jetty. This does not present any problems in boat handling as, in slack water, the vessel can proceed inshore slowly and by going full speed astern at the last moment avoid hitting the jetty. In a tide-way the operation is much simpler as the boat can stem the tide and, by allowing a small throw-off, proceed inwards down the desired transit and finish up alongside the jetty (Fig. 1).

The problem then remaining consists of fixing the boat accurately and rapidly. The taut calibrated line has been used in this connection, but its inconvenience when used

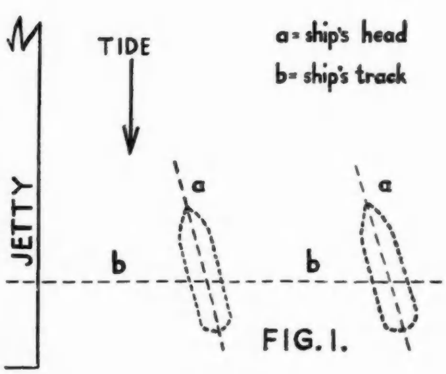
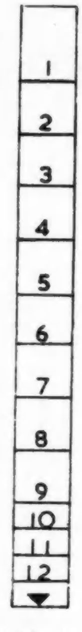


FIG. 1.

in a powered boat and for fixing a vessel under-way is obvious. Similarly, the use of simultaneous sextant angles, one subtended angle or angles measured on a 10-ft. subtense pole, are ruled out due to the impossibility of observing and logging angles at a sufficient rate to obtain the required number of fixes.

This problem can be overcome by using a Sounding Subtense Board which consists of a varying sized board designed to operate on a fixed vertical angle. In using this method the Surveyor, standing as near to the oscillators as possible, need only set his sextant at the desired angle and press the echo fix button at each indication of the distance off. In this way, by simply looking through a prism or pre-set sextant, fixes can be taken accurately at known distances off the jetty.

The Sounding Subtense Board itself can be hung from the jetty to act as a front transit mark as well as fulfil its normal use.

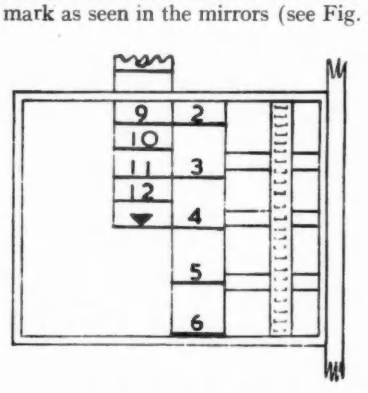


FIX	No. 1	at 10·48'	from bottom
"	2	9·43'	"
"	3	8·38'	"
"	4	7·34'	"
"	5	6·29'	"
"	6	5·24'	"
"	7	4·19'	"
"	8	3·14'	"
"	9	2·10'	"
"	10	1·57'	"
"	11	1·05'	"
"	12	0·52'	"

FIG. 2

This board should be lowered by a man stationed on the jetty who can, on the completion of each transit, move it on to the next one. If this operation is carried out while the boat is manœuvring into position for the next run no time is lost, and even a large jetty can be sounded by transits spaced at, say, 20-ft. apart in a matter of an hour or two.

The board itself consists of an 11-ft. long plank of any suitable thickness or width. Should it be made up in two $5\frac{1}{2}$-ft. sections hinged together it would be more readily portable when folded. Fig. 2 illustrates the markings and dimensions which should be painted in black on a white surface. In this way, using the required fixed angle prism or a pre-set sextant and when running in on a transit, the fix is made as each division on the board comes into coincidence with the zero mark as seen in the mirrors (see Fig. 3).



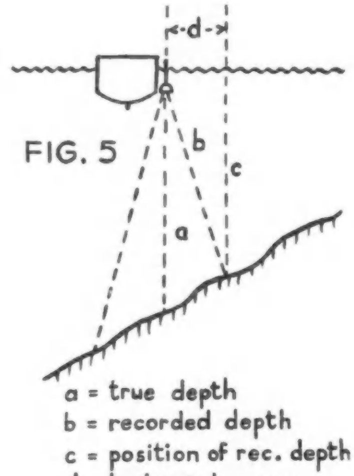
VIEW THROUGH SEXTANT AT FIX No 4 FIG. 3

This will give fixes at a distance off the board or face of the jetty, depending on the fixed angle used, and based on the following table. However, the calibrations were originally designed to operate on a fixed angle of 3° and to a maximum distance off of 200-ft.

Echo Sounding of Jetties—continued

Table giving distances off in feet when using Sounding Substense Board

Fixed Angle	Fix No. 1	2	3	4	5	6	7	8	9	10	11	12
6°	100	90	80	70	60	50	40	30	20	15	10	5
3°	200	180	160	140	120	100	80	60	40	30	20	10
2°	300	270	240	210	180	150	120	90	60	45	30	15
$1\frac{1}{2}$°	400	360	320	280	240	200	160	120	80	60	40	20



As this system is based on a right angled triangle it is essential that the board is held so that the height of the zero mark above the surface of the water is equal to the height of eye of the observer. The Surveyor can easily direct this adjustment from the boat. The reason for this is illustrated in Fig. 4. Likewise it is necessary when using a sextant, in order to avoid errors of parallax, to adjust the index mirror on a horizontal line 200-ft. distance and not on the horizon or infinity as is usually the case.

In conclusion it will be readily understood that using an Echo Sounder for surveying to such large scales is not possible should the bottom consist of a very steep slope as this brings in problems of beam angles. This difficulty is not normally met when surveying to the usual scales since any error in depth, when converted to an error of horizontal positioning, gives an unplottable difference. This is illustrated in Fig 5.

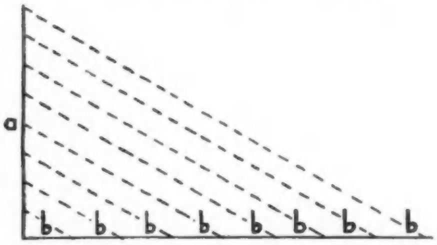


FIG. 4 a = subtense board
b = fixed angle

New Quay Wall at the Port of Ghent

Description of Reconstruction Works

(Specially Contributed)

During the month of October, 1951, the first portion of 530 metres of new quay wall in the Grand Basin was put in hand, and this was entirely completed on the 29th November, 1952, when it was formally opened for traffic by the Belgian Minister of Public Works.

The completion of this quay wall forms part of an extensive programme of modernisation and extension, by the fulfilment of which the Port of Ghent will greatly increase its facilities and augment its economic position.

The complete programme* is in the course of realisation and the various items are as follows:—

(1) A quay wall 1,085 metres long in the Bassin Echevin Giffer, with a depth of water alongside of 12.50 m.;

(2) Two sheds of pre-stressed concrete intended for the storage of sawn timber, respectively of 4,200 and 4,400 sq. metres in area;

(3) A new sub-station for the generation of electricity for some of the portal cranes;

(4) Reconstruction of the Port Arthur quay wall over a total length of 2,100 metres having a depth of water alongside of 8.75 metres;

(5) Four level luffing portal cranes of $2\frac{1}{2}/5$ tons lifting capacity having maximum and minimum radii of 36 metres and 18 metres respectively.

The opening ceremony, alluded to above, refers to the two last mentioned items, of which the following is a detailed description.

The original Port Arthur quay wall (see Fig. 1) for many years caused considerable anxiety to the technical staff of the port, and in 1944 its lack of stability was such that its continued use was attended with danger. At certain places the wall subsided more than a metre, while the first indications of forward movement made their appearance. Some simple strengthening works were undertaken to permit the temporary use of the sheds on the quay, but it was realised that only complete replacement of the quay wall would remedy the situation. Accordingly financial provision was made by the Minister of Public Works which enabled the reconstruction to be planned in April, 1950.

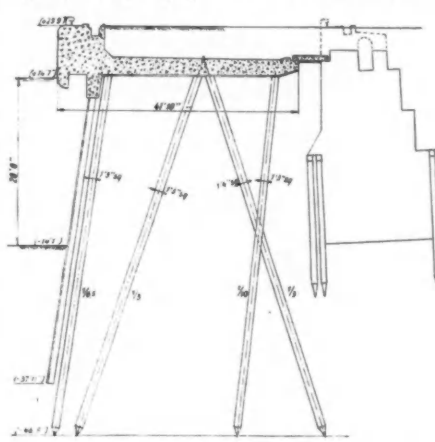


Fig. 1. Cross-section of Port Arthur Quay.

The new design comprised the demolition of the existing massive wall down to about 1 metre above water level and the construction in front of the old wall of the new quay wall. This consists of a platform of reinforced concrete 0.90 metres in thickness and 12.75 metres in width supported on bents of four reinforced concrete piles 40 x 40 cm., and a curtain wall of steel sheet piling. A small retaining wall in reinforced concrete at the front of the platform, sustains the earth filling above the platform.

The surfacing of the ground consists of sett paving in the spaces between the portal crane rails, a concrete roadway, and prefabricated reinforced concrete slabs between the inner crane rail and the concrete road.

The old quay wall is completely buried in order that it shall not exercise any unfavourable effects upon the new work.

The design adopted rendered the execution of the work capable of being carried out practically in the dry. Revolving tower cranes with a radius of 25 metres were used for placing some of the prefabricated units as well as for pitching the piles, while driving was performed with 8-ton pile drivers, at that time the most powerful in Europe.

The programme of operation was as follows:—

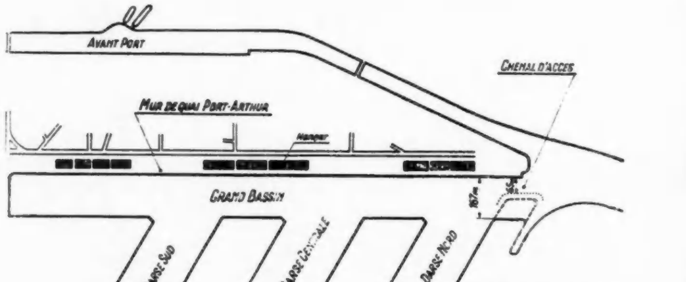
After driving the piles and sheet piling the latter were anchored to frames formed by the second and third piles of each bent;

The space between the anchored curtain wall and the old wall was filled under water with the sand provided in part by the dredging that was carried out in the Grand Basin to provide an additional half metre or so of depth for navigation;

On this filling was placed the platform or deck 12.75 metres wide, and at the same time the dwarf retaining wall was constructed on the platform;

*Described in the March 1952 issue of the Dock and Harbour Authority.

New Quay Wall at the Port of Ghent—continued



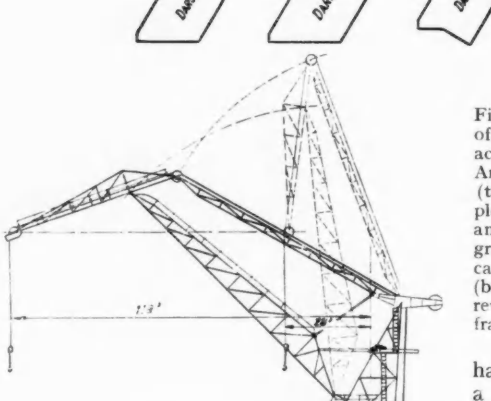


Fig. 3.

Fig. 2 (top left) Site Plan of the Grand Bassin, access channel and Port Arthur Quay Wall. Fig. 4 (top right) View of completed Quay with sheds and portal cranes. Note great width of surface for cargo handling. Fig. 5 (bottom right) Pile Driving in progress, showing revolving tower cranes and 8-ton pile driving frames

After the filling behind the retaining wall had been completed and consolidated, the placing of the rails for the railways and cranes was proceeded with, followed by the sett paving.

The surcharge load permitted on the quay surface on a width of 10 metres behind the retaining wall is 2½ tons per square metre and 10 tons per square metre on the remainder. The depth of water alongside is 8.75 metres.

The importance of this quay is indicated by the following figures:—

Length of quay ...	2,100 metres.
Number of cranes	26
Number of sheds ...	9
Storage area in sheds	66,000 sq. metres.
Total capacity of sheds	231,000 cu. metres.
Open storage area ...	115,500 sq. metres.

These works of reconstruction will be fully completed by the widening of the access channel to the Grand Bassin by the removal and dredging away of the existing promontory to the north of the Darse Nord together with the construction of an anchored steel sheet piled wall. This work will increase the width of the access channel from 65 to 167 metres (see Fig. 2).

With the completion of the construction of the new quay wall the number of cranes will be increased by four bringing the total number of cranes to 26. The new cranes (see Fig. 3) are of the new level luffing type, they have working radii of 8.50 to 36 metres and a lifting capacity 2½ to 5 tons (the latter at a radius of 18 metres). The total weight of each crane is 140 tons and the length of the jib is 45 metres.

These cranes are a Belgian type that has considerable advantages, among which is their rapidity of action. In respect of transhipment from ship to shore and vice versa, the cranes are able to load into river barges on the outside of vessels, to serve the sheds behind the quay-front, and handle goods on the whole width of the quay surface.

The works were carried out under the direction of the Mons. A. Vermeulen, Engineer in Chief Director of Technical Services of Ghent, with the assistance of the constructional and mechanical engineers of the port.

This new Port Arthur quay with its modern cranes is significant evidence of the possibilities of improvement of the port. However, the planning of the dock works must be considered conjointly with the localities and industrial areas which the port serves, as well as in relation to the general programme of modernisation of the port. In this respect the added importance of Ghent which will arise from the new maritime lock at Terneuzen, as well as the canal, is of special significance. All of these works which are part of the general plan of extension and modernisation of Ghent have been planned, put in hand and largely completed since the last war.

The Port Arthur Quay in the Grand Bassin is one of the most important of the port improvement works in that it provides immediate facilities of great value. The depth of water alongside of 8.75 metres permits the berthing of vessels of the "Liberty" type with a full cargo, and the design of quay will make it possible to deal efficiently with all operations of loading and discharge: the rails of both cranes and railways have been laid level with the paved quay surface, and upon the remaining three-quarters of the quay, surfaced with reinforced concrete slabs, modern mechanical equipment such as "fork lift" and other trucks will operate, enabling the horizontal movement of goods to be effected under the most favourable circumstances.

Shipping Record at Port of Melbourne.

The Melbourne Harbour Trust reports that in 1952, for the first time in the history of the port, the gross tonnage of shipping arrivals exceeded 15 million tons, an important feature of the record being a 10 per cent. increase in the volume of interstate shipping. The growth of shipping tonnage entering the port since the war has been as follows: 1946, 7,394,821 tons; 1947, 8,894,393 tons; 1948, 10,660,482 tons; 1949, 13,285,863 tons; 1950, 14,454,515 tons; 1951, 14,608,404 tons and 1952, 15,173,357 tons.

The Baltic and International Maritime Conference

Excerpts from Presidential Address

The General Meeting of the Baltic and International Maritime Conference was held at The Hague on the 11th inst., and the following extracts have been taken from the address given by Sir John Fisher, President of the Conference.

To-day it is my duty to review my period of office, and to offer a commentary on the future. World events have their impact on shipping in a marked degree. Shipping is not only the barometer of trade; it is particularly sensitive to the currents of political opinion and movement wherever they show themselves. We look out on a world in which three ideologies prevail, and their influence on commerce is of vital importance to us. The two outstanding philosophies are comprehended in Capitalism—free enterprise, and Communism—State deification. The third is the growth of the system of state ownership and control, and the development of the Welfare State, within a predominantly capitalist society.

The United States of America is, of course, the country in which private enterprise is fostered and encouraged as nowhere else. The result has been a remarkable expansion of American private industry. American employers and employees, both organised and unorganised, appear to have evolved a new outlook and yet one as old as the hills—appreciation of the benefits of intelligent co-operation. Workpeople who once resisted the introduction of labour-saving devices have been educated to see that the use of machinery raises real wages by increasing man-hour output and lowering costs and prices. Employers who formerly fought against the formation of trade unions have acknowledged that organised labour can help to increase productivity, maintain morale and contribute to industrial expansion.

It is unfortunate that the rest of the world suffers from an acute shortage of dollars. It is utterly impossible for debtor nations to overcome their dollar shortages unless the United States, as a big creditor nation, is prepared to accept their commodities and services. There are encouraging signs that this basic truth is recognised by responsible people in America. In March, the Mutual Security Agency (M.S.A.) published a report on the trade and customs policy of the United States, and in this was made plain what radical changes are necessary in the import policy of the United States to bring about a rational solution of the dollar problem.

There is no guarantee that American will adopt the recommendations of the M.S.A., but failure to do so can only result in the trade of the world being split up into " dollar " and " non-dollar " areas, with the latter of necessity maintaining restrictions and discriminations against the former. This will not be good for shipping. As shipowners, however, we must recognise that we have benefited from the American ideology. What we hope for and need are increased shipments to and from the United States, as well as between other countries.

As for the second main ideology, Communism, we welcome the better reason for hope to-day than at any time in recent years. If man's ingenuity and resourcefulness can be diverted from warlike to peaceful pursuits we may be upon the eve of an era of great commercial expansion and prosperity, in which the outlook for shipping would indeed be good.

The third system of philosophy, State Ownership and Social Security, appeals to many people. The thought that the State can exercise maternal care over its citizens from the cradle to the grave has its attractions, but it is necessary to pause and think deeply. People have accepted social security but have forgotten that they have to pay for it, not only in money but perhaps at the expense of those virtues which used to be considered of such prime importance—thrift, independence, self-reliance, and a readiness to take risks. It was not by a policy of " safety first " that man has survived in his present state.

In some European countries measures of social security, coupled as they are with a system of subsidies, have in the opinion of many gone too far. Anything which conceals from people the stark reality of life will in the end react to their detriment. Man still has to live by the sweat of his brow; he still has to produce before he can eat; and if the ratio of his production is out of proportion to his needs he must perforce work harder, or longer, or go without. He lives in an illusory paradise if he thinks otherwise.

Nobody who wants to work should be discouraged from doing so, yet that is one of the anomalous situations brought about by the modern system of taxation. The depredations, lawful as they may be, of tax collection may, if continued on their present scale, deprive not only the shipping industry but all industry of the means of existence. In many countries in the West the wheels of industry are showing signs of wear and tear and are slowing down. Plant is not being replaced because the capital necessary is simply not there. Many shipowners know this all too well. They are not allowed to retain from their earnings sufficient money with which to replace their ageing ships and the time is not far distant when the merchant fleets they own will be sadly depleted.

Europe has shown a marked improvement in industrial productivity, but, of course, on nothing like the same scale as in the United States. There has not been the same liberalisation of mind on the part of labour. Unfounded fears of unemployment have often had the absurd result of insistence upon the same number of workmen being employed when machinery is introduced to increase output, with the ridiculous consequence that enterprising employers are able to reap little, if any, advantage for many years to come from the capital invested in new plant, and from trying to lighten the labours of workmen. This is true of many industries. We find it on the dockside and we find it in ship-repairing, to mention only two instances. Shipping would have been hampered if every vessel using oil as fuel had to employ the same number of people required in a coal-burning ship. Shipowners, at any rate, have reason to congratulate themselves upon the foresight and enlightened minds of the leaders of the seamen's organisations in this respect.

If the merchant navies of the world are to hold their own the cost of shipbuilding will have to come down, and the same applies to repairs. Here we may see before long something happen which may have a startling effect on shipbuilding and repairing costs—I mean a surplus of steel. This may appear an optimistic anticipation, but there are signs and portents for those in a position to observe them. The high level to which repairing costs have soared also affects insurance, as instanced by the London market increase of 10% this year.

Nor are these the only items affected. It costs the fantastic sum of six dollars a ton—roughly £2 sterling—to load or discharge a general cargo in New York. Can such costs be justified? How long will it be before the law of diminishing returns begins to apply to cargo shipments? It is true that here and there one can see a few bright spots in the improvement in turn-round in ports, but unfortunately this is not a general experience. It is still not fully realised that anything that adds to the cost of transport is inevitably reflected in the price which has to be paid for the product carried. Carriage by sea is still the cheapest form of transport, but it must be remembered that there is an ecomoic limit to the freight rate any commodity, or piece of merchandise, or even passengers, can bear.

In another sphere revolutionary progress has been made. We have moved into the Atomic Age. Coal has largely given way to oil—will oil succumb to atomic power? A leading British industrialist has forecast that within ten years the cost of power produced from uranium will be cheaper than that produced from coal, and presumably from oil also.

There is one direction at least in which the shipping industry is in the forefront of progress—the development of the gas turbine for ship propulsion. Every credit is due to shipping, shipbuilding and engineering companies for their research and development work in this field.

Neither the predicted uranium power age nor the rapid expansion of air transport will supersede seaborne carriage of bulk cargoes. There will always be a demand for tramp vessels to carry commodities such as ore, grain fertilisers, timber and sugar. For long-distance trading it may well be that vessels will be bigger and faster and we may find tramp ships of 15,000 d.w.t. and over, with a speed of up to 14 or 15 knots coming into favour.

It is significant that where bulk buying has been replaced by ordinary commercial practice; trade has resumed its normal channels but the 10,000 tons deadweight tramp has maintained its hold on the market and the 5,000/7,000 tons deadweight ship, which has not been built to anything like the same extent, and should therefore be in short supply, is finding the market more difficult

The Baltic and International Maritime Conference
(continued)

than does her larger sister. Where merchants have taken to the smaller tonnage sizes they seem to have gone to the other limit, as in the case of the timber trade. Having regard to the large number of ports of limited draught it is reasonable to anticipate that the 5,000/7,000 tonner will come into her own again when normal trade conditions are once more in full swing. In the short sea trades it seems probable that the small coal-burning tramps up to 2,500 tons deadweight will gradually disappear and be replaced by motorships or oil-fired steamers. Even to-day there is evidence of the difficulty coal-burning tramps have in holding their own in competition with motor vessels. At the beginning of March the figures of vessels laid up because of the scarcity of suitable cargo and the low rates of freight, clearly showed that it was the small coal-burners which accounted for the greater part of the tonnage withdrawn from service in a number of European countries, including Scandinavia. One of the disadvantages of these small coal-burning tramps is that they have to carry a relatively big crew. Thus it is not surprising that many owners, when acquiring new tonnage, incline to motor vessels.

I would like to utter a word of warning about the frequently misused expression "customs of the port." Carver in his "Carriage of Goods by Sea" (9th Edition, 1952) puts the position quite clearly when he says that custom is not law; it depends for its operation on contract. He adds: "So that unless the circumstances under which the contract was made were such that a knowledge of the custom, and an intention to incorporate it, can be properly assumed, the custom ought not to qualify, or add to the effect of the contract as interpreted by the law." This feeling expresses the attitude of most practical shipping people on the subject. There are many examples of port authorities and local Chambers of Commerce holding to customs which have little to do with the actual and correct procedure of a particular trade.

Flag discrimination is always a nuisance, to say the least of it, to shipowners. It is distasteful to have to criticise our American friends, but we cannot pass over in silence what has become known as the 50/50 rule. Marshall Aid, that remarkable constructive plan whose value in stabilising conditions in Western Europe can never be over-rated, contained this bad flaw—a provision that at least 50 per cent. of the cargoes must be carried in United States ships. The discrimination in favour of American flag vessels, spread over 50 per cent. of the Marshall Aid cargoes, and more recently Mutual Security Aid cargoes, has been a big drain on the dollars originally allocated by the United States. We welcome the recommendation of the Public Advisory Board of M.S.A. that the 50/50 rule should be dropped. If this is accepted, competition for the cargoes concerned will be restored to a fair commercial basis.

Progress in Hydraulics Research

Excerpts from Annual Report

"Hydraulics Research, 1952," published earlier this month (H.M. Stationery Office, price 6s. or 1 dollar 40 cents U.S.A. currency, by post 6s. 3½d.) describes the gradual expansion of the work at Wallingford. The Research Station is still building and facilities are limited, but in spite of this several new investigations were started during the year.

For example, a study was made of the changes reported to be taking place in Morecambe Bay. British Railways run services from there to Ireland and the Isle of Man. Heysham Harbour in the bay was apparently silting up, and the navigable channel becoming more and more shallow and narrow. The railway authorities were afraid that the channel would eventually become useless except at high water. A detailed analysis of ordnance surveys made between 1845 and 1941 showed that the changes occurring there are part of a long cycle. There is no evidence that Morecambe Bay is silting progressively.

The Thames Model

Work on the Thames model included experiments on the problem of silting in the Surrey Commercial Docks. Large quantities of silt are carried in with the water used for impounding and settle in Lavender Dock. The model was used to find out if a weir across the Lavender Lock entrance would stop or reduce the silting. The experiments showed that the proposed weir would have little or no effect.

Work on the first major problem of the river to be considered is in progress on the Thames model. This is the siltation that occurs in the tidal basin at Tilbury. To maintain a depth of 24-ft. there, an average of 400,000 cubic yards of material must be dredged every year from the basin. Part of the model round the Tilbury area was reconstructed so that this problem could be studied in greater detail.

Dredging at Yarmouth

A dredging problem of a different kind came from Norfolk. Here, dredging at the entrance to Great Yarmouth harbour caused an increase in the rise and fall of the tide upstream at Reedham Marshes. This, in turn, brought about bank erosion at Seven Mile House. Several proposals for dealing with this have been put forward but most of them have been ruled out either because they would be merely temporary solutions or would cause erosion elsewhere. A repelling spur seemed to be promising but it would have to be investigated by means of a model.

New Zealand

On behalf of Lyttleton Harbour Board, New Zealand, designs for extending the present harbour are being studied. Port Lyttleton is peculiar because of its geological formation. The bed of the inlet consists of a very fine material derived from loess and is practically flat from cliff to cliff. This makes it possible for waves to travel up into the harbour from the sea almost without losing height. The extensions to the existing inner harbour must be designed so that they can be added piecemeal and at each stage give protection from the swell caused by the waves.

Two models of the harbour have been built, one in which both tides and waves can be generated and another to study wave action in particular. The rates of silting in the present harbour and in the new one will also be investigated.

Coast Erosion

Coast erosion is one of the most important subjects with which the station has to deal. It concerns many local authorities in the country. A survey was begun early in the year in the areas of Hurst, Christchurch, Bournemouth and Poole. For the first season the main aim was to develop satisfactory working techniques and to find out the accuracy and speed with which the work could be done. The beach was marked in sections and a boat fitted with an outboard echo-sounder was used to make profiles of the beach from the cliff or seawall to 2,000-ft. from the shore. A new device for recording the drift of water at the sea bed is expected to be valuable for this work. With this instrument, it is not necessary to wait for measurable changes to take place to know what is happening. The recorder was used only once, at Southbourne, where it was placed seaward of the breakers and watched from the cliffs. The drift at the bed was shoreward. It is impossible to say at the moment in what conditions this drift would be reversed.

Ports Authority for Nigeria

It was recently announced in Lagos that by next January a Ports Authority will be set up in Nigeria. A report setting forth proposals for the constitution of the Authority will be laid before the House of Representatives in August, while legislation will be introduced simultaneously to give legal existence to the Authority, which will be directly responsible to the Minister of Transport. The Authority will take over control of all harbours now managed by the Marine Department and wharves administered by the Nigerian Railways. The Authority will also be responsible for development of ports and port facilities. One of its first duties will be to solve the problem of congestion at Lagos and Port Harcourt, while later it will be responsible for the development of inland waterways and wharves.

The Southampton Harbour Board

Celebration of 150th Anniversary

(Specially Contributed)

THE Southampton Harbour Board, the Statutory Authority for the Port and Harbour of Southampton, celebrated its 150th anniversary on April 18th of this year, for on that day of the year 1803, the Act of Parliament creating the Board came into operation and the first meeting was held.

Unlike most other great commercial ports, such as London, Liverpool, Bristol, etc., the Port and Dock authorities at Southampton are not a single entity, the Docks, although within the port area, being administered by the Docks and Inland Waterways Executive of the British Transport Commission, whilst the Harbour Board, as the Port Authority, exercises jurisdiction over the approaches to the docks, and has the control and operation of certain quays and piers as mentioned hereafter.

The docks of Southampton, as becomes a port of such prominence, have been the subject of several articles in the "Dock and Harbour Authority" during recent years and are therefore but briefly referred to here.

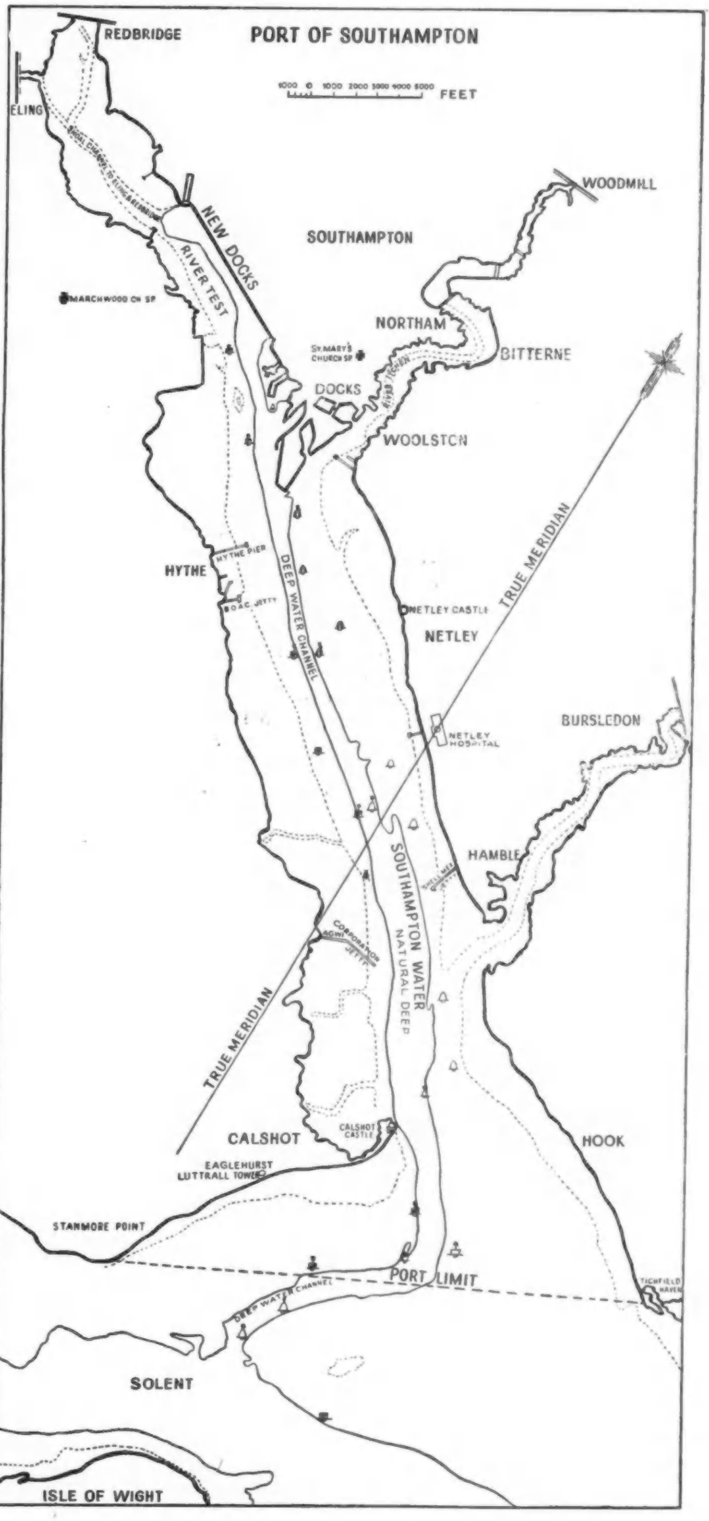
The responsibilities of the Harbour Board extend northwards of an imaginary straight line drawn from Stansore Point on the western side of the entrance to Southampton Water to Hillhead on the eastern side and includes the whole of Southampton Water and up to the causeways at Redbridge and Eling in the River Test, to Woodmill in the River Itchen and up to Bursledon Brdige on the Hamble River.

The Harbour Board is a public trust operating under private acts of Parliament and is an appointed and elected body consisting of twenty-six members. Members are appointed by:—Southampton Borough Council (8 members), British Transport Commission (3), Admiralty (1), War Office (1), Trinity House (1), Ministry of Transport (1) and Southampton County Council (1); and members are elected by:—Owners of foreign-going vessels (4), owners of coasting vessels (2), Southampton Chamber of Commerce (2), Waterside Frontagers (1) and Traders (1), Appointments are made and elections held every three years.

The waterways of the port under the jurisdiction of the Harbour Board below high water line comprise an area of $18\frac{1}{4}$ square miles. The total length of foreshore under the Board's jurisdiction is approximately 45 miles and no works below high water line can be undertaken without the consent of the Ministry of Transport (under the Coast Protection Act of 1949) and the Southampton Harbour Board.

The Harbour Board is the Local Lighthouse Authority, and is responsible for buoying and lighting the channels. It also has power to dredge, maintain and generally improve the waterways under its control, and the magnitude of this task will be appreciated when it is remembered that the approach channels to Southampton are used regularly by the world's largest liners. All ships coming into the port are liable for harbour dues to the Board and out of this revenue the Board discharges its responsibilities enumerated above. The Board is also the Local Sea Fisheries Committee.

Before giving details of the present-day activities of the Board it will be as well to deal with its history. The industrial revival at the close of the eighteenth century and opening of the 19th saw the commencement of great harbour works at other ports and in 1803 the burgesses of Southampton awoke to the realisation of the potentialities of the Port of Southampton. Accordingly an Act of Parliament was passed in 1803 by which the control of the port was transferred from the Corporation. Ten Harbour Commissioners were appointed, who, with the Mayor, Recorder and Councilmen of the town were empowered to construct docks, improve the port and exercise jurisdiction over the waters of the port. This Act also stipulated that certain dues, known as Petty Customs, which had been imposed on all Imports and Exports by the Corporation during the reign of Henry III, should be abolished and that compensation of one-fifth of Harbour Dues be paid by the Harbour



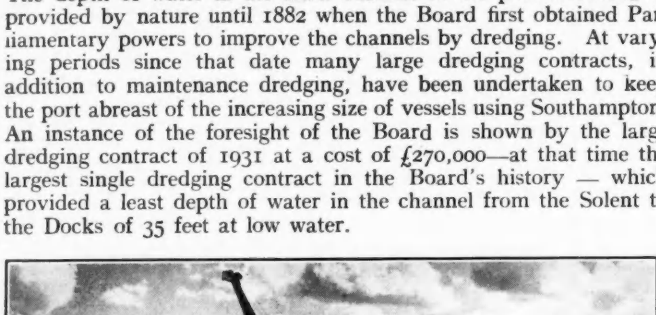
Southampton Harbour Board—continued

Commissioners to the Corporation, an arrangement which continues to the present day.

Following the passing of the 1803 Act, the Harbour Commissioners immediately commenced to improve the waterway and shore approaches. They purchased properties in order to improve the access to the Town Quay, built warehouses, purchased cranes and eventually embarked upon the first major extension of port facilities by building the Royal Pier to accommodate vessels operating services to the Channel Islands, France and Isle of Wight. The Royal Pier was officially opened on July 8th, 1833, by H.R.H. Princess (afterwards Queen) Victoria, who was accompanied by her mother the Duchess of Kent.

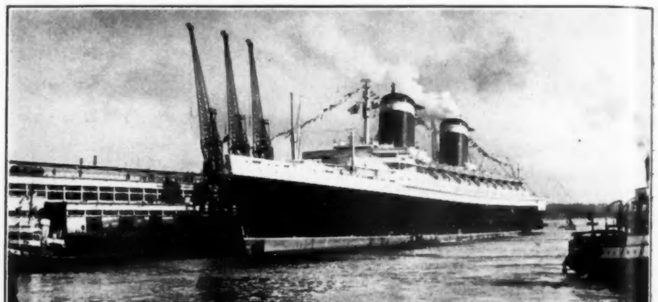
Owing to lack of capital, however, the construction of Docks remained in abeyance due to the relatively heavy expenditure previously incurred in the development of the port, and it was left to the Southampton Dock Company to commence the building of Southampton Docks, the foundation stone of which was laid in 1838. In the latter years of the nineteenth century, however, the Southampton Dock Company found they did not have sufficient capital to develop the docks further and the question arose as to some other body taking over the docks. The Southampton Corporation voted against a proposal that they should become the dock owners and the Harbour Board likewise refused, and it was left to the London and South Western Railway to take over and develop the docks. It was under the aegis of this Railway and that of the Amalgamated Southern Railway, that the Southampton Docks became one of the major ports of Great Britain. Among a number of improvement works which have been carried out are the Ocean Dock, the Floating Dock, new quays on the River Test, together with the Graving Dock, and more recently, the new Passenger Terminal in the Ocean Dock.

To revert to the present-day responsibilities of the Harbour Board; the biggest item of port conservancy is that of dredging. The depth of water in the main channel of the port remained as provided by nature until 1882 when the Board first obtained Parliamentary powers to improve the channels by dredging. At varying periods since that date many large dredging contracts, in addition to maintenance dredging, have been undertaken to keep the port abreast of the increasing size of vessels using Southampton. An instance of the foresight of the Board is shown by the large dredging contract of 1931 at a cost of £270,000—at that time the largest single dredging contract in the Board's history — which provided a least depth of water in the channel from the Solent to the Docks of 35 feet at low water.



Timber vessel discharging at Berth B, Town Quay.

The post war years have found the Board equally alert to the needs of shipping and in addition to the completion of schemes for deferred maintenance dredging, work on the largest dredging contract ever placed by the Board was completed in 1951. This scheme, costing nearly £700,000, involved the removal of 3½ million cubic yards of material. This contract comprised three principal items, each in itself a large project:—(1) Dredging away the port hand western margins of the western approach channel to a least depth of 38 feet L.W.O.S.T. to give greater freedom to the largest liners turning inwards, (2) Dredging away the easterly corner of the Calshot Spit to a 4,000-ft. radius curve to give an easy turn for liners, (3) Rectifying the easterly margin of the channel between the N.W. Netley Light Buoy and the Cadland Light Buoy. An interesting feature of this dredging contract was the disposal of large quantities of spoil ashore to reclaim marshland between Fawley and Calshot.



The world's fastest liner, the new *United States* at Southampton Docks.

Other conservancy responsibilities of the Harbour Board include the buoying and lighting of the port and provision of aids to navigation and control of shipping. The Board's Signal Station at Calshot is continuously manned throughout the twenty-four hours, and the Board is now in course of establishing a Port Control and Information Service including a system of ship-to-shore radio telephone control with the Control Station at Calshot, which will enable radio-telephonic communication to be established between important shore points and ships arriving or sailing. The scheme includes two radio-equipped launches to patrol Southampton Water.

In addition to the freight traffic handled at the docks, administered by the Docks and Inland Waterways Executive, a considerable cargo trade is carried on at the Town Quay, which is owned, controlled and operated by the Harbour Board. It has a frontage of 4,500-ft. and can accommodate ships of about 350-ft. in length with 19-ft. draught. Electric luffing cranes up to 15-ton lifting capacity are installed throughout the quay, which is equipped with modern two-storied warehouses. Railway lines alongside each berth and warehouse connect with British Railway main lines. The gross tonnage of ships using the Town Quay annually is over half a million and the cargo handled averages 150,000 tons, which represents nearly one-seventh of the total cargo handled at Southampton Docks. Prior to 1939 the bulk of quay traffic consisted of coastwise cargo, but the decline in this traffic since the war has caused the Board to extend its activities and the Town Quay traffic now largely consists of imports and exports between France, Sweden, Finland, Spain, Canada, etc.

The Royal Pier, also owned by the Board, deals with over 600,000 boat passengers annually and, including promenaders, a total of nearly one million people use the pier each year. The pier has floating pontoons available at all tides enabling private motor cars and goods lorries to be driven on and off steamers sailing between Southampton and the Isle of Wight.

The River Hamble, the home of many famous yachting clubs, is within the Harbour Board's jurisdiction, and over 400 moorings have been provided or licensed by the Board.

The Admiralty have recently taken over the premises formerly used by the British Power Boat Co. at Hythe for use as a small craft repair and maintenance depot. The Admiralty are making improvements to the jetties and slipways and licences have been granted by the Harbour Board for additional moorings.

In 1952, the British Electricity Authority commenced construction on the site of the Authority's new generating station at Marchwood, and the Board was consulted in connection with the construction of the wharf-face etc. Considerable improvement will be

(concluded at foot of next page)

British Transport Commission's Docks

Anticipated Trading Surplus for 1952

Docks owned by the British Transport Commission are believed to have made in 1952 the biggest trading surplus since they were taken over in 1947. In 1951 the docks showed their first surplus—£817,241—and figures for 1952 to be published later this year are expected to show an even better result.

Docks controlled by the Docks and Inland Waterways Executive form the major part of those owned by the Commission and comprise about a third of the docks of the United Kingdom. During 1952 they showed a decline in imports, but an increase in exports. Imports totalled 24,250,000 tons. This slight decrease was due to the cessation of emergency coal imports from America; other decreases were in timber, chemicals and general cargo. Increases were made in oil, iron and steel manufactures and iron ore. Exports, on the other hand, rose by nearly six million tons to 32,250,000 tons, the main increases being four million more tons of coal and 1,250,000 more tons of oil.

In an endeavour to reduce costs and speed up the turn-round of ships in port, several improvement schemes have been undertaken. Much reconstruction and modernisation has to be done in addition to the carrying out of war damage repairs, but restrictions still exist on capital expenditure.

Among the schemes in progress is the reconstruction of passenger and cargo accommodation at Southampton at a cost of £900,000 for providing a supplement to the Ocean Terminal to handle South African traffic. At Hartlepool, work is due to begin within the next two or three months on the construction of a £330,000 lightening berth which is designed to enable the port to handle the largest ships in the timber trade. The berth, which will have a quay length of 480-ft., will cover five times the area of the present berth. Larger cranes will be installed later.

Another improvement scheme, estimated to cost £470,000, is to be undertaken at Middlesbrough Dock by the Docks and Inland Waterways Executive, subject to the approval of the Transport Commission. To meet the requirements of shipowners and traders, No. 10 Quay, which has hitherto been used exclusively for shipping coal, is to be developed for general cargo working by the addition of two single-storey transit sheds, 385-ft. and 350-ft. long respectively, eight 6-ton and two 10-ton level-luffing electric cranes, as well as ample rail and road access.

A modern system of cranes, costing £950,000 is to be installed in the King George Dock, Hull, and reconstruction of a quay in this dock at a cost of £210,000 is now in hand. Proposals are also being considered for other reconstruction work at Hull which it is estimated will cost approximately £2,000,000.

At Cardiff, Newport and Swansea good progress is being made on a scheme, amounting to £525,000, for the electrification of pumping machinery and the modernisation of the electrical distribution system. At Fleetwood improvements to enable larger trawlers to use the dock are nearing completion, at a cost of approximately £160,000.

Southampton Harbour Board—continued

made in the area by reason of the dredging to be carried out by the British Electricity Authority, and when the generating station is operating to capacity an increase is expected in the number of colliers entering the port with coal for the new station.

Over 100 ships, each with a gross register tonnage exceeding 14,000 regularly use the Port of Southampton.

Although, as previously stated, the Port and Dock authorities at Southampton are separate, the closest liaison and harmony exists between these two bodies, a fact underlined by the recent election of the Docks and Marine Manager (Mr. R. P. Biddle, C.B.E.), as Deputy Chairman of the Harbour Board.

In the one hundred and fifty years since the original Harbour Commissioners first met, the annual tonnage of shipping using the port has grown from 40,000 N.R.T. in the early 1800's to 18,747,436 N.R.T. in 1952, a development which reflects the greatest credit on the vision and energy of all connected with the Port of Southampton.

Survey of U.S. Harbours

Depth of Water Limiting Factor

According to a report issued recently by the U.S. Government, the current trend in world shipbuilding, particularly in respect of tankers, is toward large and deep-draft ships, and bulk carriers with a draft of 40-ft. or more would now be under construction if it were not for the limiting depths of harbours and channels. The report was made by a committee of military, shipping and shipbuilding officials after a six-month study of the depths of water to be created in U.S. harbours and their entrances to comply with ship construction.

Similar reports are being prepared by all the major maritime nations on their port facilities. These are to be submitted to the Permanent International Commission of Navigation Congresses, with headquarters in Brussels, Belgium. The commission plans to incorporate the reports in an international paper on the subject.

Many Ports Surveyed.

The U.S. ports covered by the study included Portland, Me., Boston, New York, Philadelphia, Baltimore, Hampton Roads, Savannah, Mobile, New Orleans, Port Arthur, Galveston, Houston, Corpus Christi, Los Angeles, Long Beach, San Francisco, Portland, Ore., and Seattle.

The report stated that an increase in capacity and draft of vessels had preceded a related increase in the depths of seaports, with a resultant disadvantage to shipping. Ships had not been able to carry capacity cargoes, had had to lighten cargoes to reduce draft, had lost time waiting for high tide, and had sustained damages because of inadequate clearance in channels and harbours.

An example mentioned in the report, is that 45,000-ton tankers are being constructed with a loaded draft of 37-ft. 6-in. The owners plan to load the vessels only to 34-ft. 6-in. or a corresponding loss of some 5,000 tons of oil, because the channels in the harbour they will enter are not sufficiently deep.

The committee noted that channel depths have been based in the past on the needs of existing shipping using a port and recommended that future channel depths be considered from the viewpoint of the trends in world construction as to size, breadth and depth. In their view it was unlikely that the draft of large passenger ships would be increased in the foreseeable future, but the trend in other types was toward deeper ships.

The draft of combination passenger and cargo ships has increased in 25 years from 24-ft. 6-in. to about 29-ft. The modern "Mariner" class cargo ship, at almost 30-ft., draws six feet more than the cargo ship of 30 years ago. The draft of large tankers 30,000 tons and upwards—which at present make up 25.9 per cent. of world tanker construction—has increased in 10 years from 30-ft. to 38-ft.

Book Review

Myhre's Handbook of Baltic and White Sea Loading Ports. Eleventh Edition, 1082 pp. Published by J. Jorgensen & Co., 16, Krystalgade, Copenhagen, Denmark. Price £4 net, including postage.

This handbook has now been thoroughly revised and extended and contains full particulars of harbour conditions and facilities, pilotage and towage, port, stevedores, and other charges, and lists of shipbrokers, stevedores and shippers, together with other information concerning ports and harbours in Sweden, Finland, Russia, the White Sea, Norway, Denmark and the Netherlands. Up-to-date information regarding facilities in Poland and Germany and an enlarged chapter on United Kingdom ports are also included. A special section gives full information regarding freight facilities at all the major airports in countries covered by the handbook. This section has proved to be useful to the shipping trade when despatching crew members, spare parts, general goods, etc.

This new eleventh edition has been rendered necessary by the considerable alterations to port facilities and charges during the post-war years, and it will undoubtedly prove even more valuable than earlier editions which, for over 40 years, have been indispensable as a book of reference for all interested in the Baltic, White Sea and North Sea trades.

New York Port Facilities

Report on Special Survey

A long-term modernisation programme for the harbour of New York, to be undertaken as soon as finances permit, has been recommended by Messrs. Sanderson and Porter, a United States engineering firm who recently completed a special study of the port at the request of the New York State Crime Commission.

The report said that while present facilities at the port are far from satisfactory, they have so far been able to cope with all demands arising from ocean traffic, including the peak war-time load. Other proposals advanced to effect an improvement include taking active steps to improve labour conditions in the port and to secure equalisation of rail freight rates with those prevailing in Baltimore and Philadelphia.

Competition with other U.S.A. Ports.

If over-all tonnage figures are taken as a measure of port activity, New York has lost position with respect to other U.S. ports, the report states, " This, however, is not so much a true index of competitive conditions, since the large tonnages reported by other U.S. ports have been of such commodities as coal and metallic ores, for which New York has never been in a position to compete, and to large petroleum receipts, notably at Philadelphia, which has experienced a big increase in refinery capacity."

In competitive categories, New York had held its position with respect to imports and exports and coastwise receipts. The fact that coastwise trade had deteriorated from the pre-war 37 per cent. to the 30 per cent. of the 1949-1951 period was due mainly to competition from road transport rather than to diversion of cargoes to other ports.

Port Improvement Proposals.

The report discusses the proposals for port improvements advanced during recent years by the Port Authority, World Trade Corporation, and Department of Marine and Aviation, observing that there could be no question about the necessity of a long-term plan for pier modernisation and replacement as all the plans suggested. Many of the 159 piers owned by the city were either too short or too narrow to allow efficient cargo handling, and many of the berths were inadequate for convenient manœuvring of lighters and modern vessels.

In conclusion the report states, " In our opinion the conditions and arrangements of the city-owned piers and waterfronts are not such as to handicap unduly the activity of the port. This is not to say that we think conditions are satisfactory, however. But we are inclined to believe that the urgency for large scale and rapid improvements has often been overstressed."

OFFICIAL APPOINTMENTS.

DOCKS AND INLAND WATERWAYS EXECUTIVE (HUMBER PORTS).

SECTIONAL HEAD. DRAWING OFFICE.

Applications are invited for the post of Sectional Head, Drawing Office, Civil Engineer's Department, Hull. Salary range £714 15s. 0d. to £752 15s. 0d.

Applicants must be competent and experienced reinforced concrete designers.

The candidate selected for appointment will, where eligible, be expected to join a contributory superannuation scheme, and in this respect to comply with whatever provisions are decided upon later for the staff of the Executive as a whole.

Applications giving details of age, experience and present position should reach the Chief Docks Manager, Docks and Inland Waterways Executive, Dock Office, Hull, not later than 14 days after the publication of this advertisement.

TENDERS WANTED.

SOUTHAMPTON C.B.C. invites Tenders for the REMOVAL and DISPOSAL at SEA of SEWAGE SLUDGE from the four Corporation Sewage Works. Maximum quantity 50,000 cubic yards per annum. Specification and Conditions may be obtained from the Borough Engineer and Surveyor, Civic Centre, Southampton, on payment of £3 3s. 0d. deposit, returnable upon receipt of bona-fide Tender. Tenders by noon, Monday, 6th July, 1953.

TENDERS WANTED (Continued).

REPUBLIC OF INDIA
MINISTRY OF DEFENCE.

DEVELOPMENT OF NAVAL DOCKYARD — BOMBAY
comprising
DREDGING, RECLAMATION, WHARVES, GRAVING DOCK AND ANCILLARY WORKS.

Civil Engineering Contract No. 1.

The Ministry of Defence, New Delhi, invite Civil Engineering Contractors to tender for Contract No. 1, being the first stage in the Development of the Naval Dockyard at Bombay.

The work is of considerable magnitude and tenders will be considered only from Contractors of established reputation in Dock and Harbour construction.

Formal Tender Documents will be available during July 1953 to interested firms of contractors, on application to the Ministry's Consulting Engineers, Sir Alexander Gibb & Partners, Queen Anne's Lodge, Westminster, London, S.W.1.

The closing date for tenders, which are to be addressed to Major General H. Williams, C.B.E., Engineer-in-Chief, Army Headquarters, New Delhi, India, will be 4 p.m. on 30th September, 1953. Tenders will be invited on the basis of a priced Bill of Quantities with variation due to rise or fall in certain basic materials only.

A Preliminary Statement for the use of Contractors proposing to tender for the Civil Engineering Contract No. 1 and giving further details of the location and extent of the contract works is now available from the above-mentioned Consulting Engineers, to whom application for copies should be made.

This Preliminary Statement is available now so that Contracting Firms desiring to submit tenders may make early arrangements to visit Bombay and obtain all the essential information at the site. A representative of the Consulting Engineers will be available at Bombay to meet the Contractors, during the period from 13th to 31st July, 1953.

Applications for formal contract documents from bona fide firms of Contractors who intend to tender for the work should be made to the Ministry's Consulting Engineers, Sir Alexander Gibb & Partners, Queen Anne's Lodge, Westminster, London, S.W.1, as soon as convenient, but in any event not later than 15th August, 1953. The contract documents will be despatched to Tenderers as soon as they are available for issue.

The Contractor whose tender is accepted may be required to furnish a security deposit as specified in the Contract Documents.

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